United States
Department of
Agriculture

Forest Service

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Protection

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FSCBG Model Comparisons With The 1992 Charter Orchard Peach Twig Borer Study - Spray Deposition And Drift

FHTET 96-11
July 1996

Pesticides used improperly can be injurious to human beings, animals, and plants. Follow the directions and heed all precautions on labels. Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides where there is danger of drift when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment, if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

NOTE: Some States have restrictions on the use of pesticides. Check your State and local regula-

CAUTION: PESTICIDES

Cover Photo
Ag-Cat aircraft spraying ult
volume of Bacillus thuringie
insecticide over isles between
almond trees. Vehicles used to
mark the isles. Photo by J. Barry

FHTET 96-11
C. D. I. Technical Note No. 96-04
June 1996

FSCBG MODEL COMPARISONS WITH THE 1992 CHARTER ORCHARD PEACH TWIG BORER STUDY - SPRAY DEPOSITION AND DRIFT

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Foreword

The 1992 Charter Orchard Study was a joint effort conducted by the USDA Forest Service and the University of California Extension/Integrated Pest Management Program. The study was designed by Frank Zalom and myself with sensitivity to need for multiple and replicated treatments, for avoidance of spray drift on other replicated and control blocks, and for need to balance sampling frequencies against a backdrop of low budget, a narrow time window to apply the spray, a lack of instruments to characterize the micrometeorology that influences spray deposition and drift, and an uncertain availability of spray aircraft for application within the time window. These are the unfortunate realities of today's field testing.

Sampler selection and assay were other concerns. Realizing that there was no reliable method of counting and sizing drop stains on the soda straws and answering questions about reliable methods for accurate assay of drop stains on Kromekote deposit cards, I decided to do the assessment by manual methods. This was a very tedious and time consuming process, but one that produced numbers with a high level of confidence. The resulting analyses, presented by authors (Roltsch et al. 1995; and MacNichol, this report), showing consistency and comparability between straws and cards, points out the importance of attending to details in sampler assay.

In addition to those of us who joined Roltsch to report on this study, I contracted Continuum Dynamics, Inc. of Princeton, NJ, to review the data and to make FSCBG model predictions to field observed data. The Roltsch paper and this report document our first attempt in California to aerially apply the biological insecticide <u>Bacillus</u> <u>thuringiensis</u> (Bt) to orchards by aircraft using ultra low volume application.

The 1992 Charter study preceded another successful study at the Hennigan Orchard, Chico, CA in 1994. Attempts to conduct continuing studies in 1995 and 1996, however, fell victim to unusual cool and wet conditions during the February and early March period. Future testing to further demonstrate the positive economics and operational approaches to ultra low volume application of biological insecticides like Bt is dependent upon continued encouragement and cooperation from growers like Ray Charter and Bob Hennigan, and the support of the applicator and pest control agent industries. Let's continue to build upon these initial successes, form partnerships and advance this and other environmentally safe and economic methods of applying insecticides.

JOHN W. BARRY
USDA Forest Service
Davis, CA
May 31, 1996

Foreword

The 1992 [illegible] was funded by the USDA Forest Service and by [illegible] Extension [illegible] Management Program. The study was designed by [illegible] and myself with [illegible] to identify [illegible] and document the [illegible] of [illegible] [illegible] with [illegible] and [illegible] [illegible] the [illegible] of [illegible].

[illegible] selection [illegible] [illegible] [illegible] of the [illegible] [illegible] [illegible] as [illegible] [illegible] [illegible] [illegible] [illegible].

In addition [illegible] [illegible] [illegible] the [illegible] [illegible] in California [illegible] [illegible] [illegible].

The 1992 Chaney study provided [illegible] [illegible]. Attempts to continue [illegible], however, will [illegible] to unusual cool and wet conditions during the [illegible] and early [illegible] [illegible] [illegible] local partnerships and [illegible] [illegible].

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Davis, CA
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Executive Summary

This paper presents the results of an ultra-low volume (ULV) aerial spray application delivered by aircraft to a broadleaf orchard. Two field trials were conducted by the USDA Forest Service in cooperation with the University of California (Davis) Extension IPM Program and others, at Charter almond orchard, Colusa County, CA, during February and March 1992. The objective of the Charter study was to evaluate the deposition pattern of the insecticide *Bacillus thuringiensis* (Bt), applied ULV from a fixed-wing aircraft under different foliage conditions of the almond orchard, and to compare two sampling devices (Kromekote cards and polyethylene straws) and assess the practicality and effectiveness of each. For each stage of foliage (blossom expansion and petal fall), a formulation of Bt was applied aerially over portions of the orchard and deposition data were collected from sample trees positioned in treated as well as untreated areas. On either side of the sample trees, the two types of sampling devices were positioned at two elevations in the canopy and on the ground. Twig samples were also gathered. This paper reports on deposition throughout the orchard canopy in treated and untreated areas as predicted by the USDA Forest Service Cramer-Barry-Grim (FSCBG) aerial spray model and compared to the deposition observed on each type of collector. FSCBG model simulation results compared to observed field data are presented for each stage of foliage development and for both types of collectors, and show good correlation with observed deposition data, with correlation of mean predicted and observed deposition of $R^2 = 0.44$ for trial 1 and $R^2 = 0.90$ for trial 2. Drift observed outside of the treatment areas is also evaluated.

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1. Introduction

Field trials conducted at Charter orchard, Colusa County, California in February and March of 1992 comprise the first known commercial use of an ultra-low volume (ULV) aerial application of the biopesticide *Bacillus thuringiensis* (Bt) on a broadleaf orchard in California. The target insect population for this aerial spray study was the peach twig borer, *Anarsia lineatella*. Since the mid-1970's organophosphate insecticides plus oil have been used as a dormant spray to control this insect. The California Environmental Protection Agency has given notice that organophosphate dormant spray will not be allowed in the future (Roltsch et al., 1995). Thus, bloomtime spraying of Bt, a biopesticide, is an attractive alternative means of controlling the peach twig borer.

Applications of bloomtime sprays need to be made during a relatively short time period, and cannot always be accomplished with ground sprayers (particularly when large areas are involved or when the ground is wet). The USDA Forest Service (Forest Pest Management staff) and its cooperators have recently conducted two studies for the purpose of evaluating aerial application of Bt in almond orchards at various stages of flower and foliage: this one at Charter orchard in 1992, and another at Hennigan Orchard in Chico, California, in 1994 (MacNichol, 1996a and 1996b; MacNichol and Teske, 1996; Teske et al., 1993; Zalom at al., 1994a and 1994b).

The first operational forest spraying of Bt in the west was a low volume application in the Bitterroot National Forest, Montana, conducted by the USDA Forest Service (Dewey et al., 1973) using Abbott Dipel 4L wettable powder. By the late 1980's, the USDA Forest Service was using ULV applications, defined as undiluted formulations applied at less than one gallon per acre, to successfully control western defoliations (Skyler et al., 1990). The success since the mid-1980's of ULV over low volume diluted applications is attributed to increased potency of the Bt formulations, use of fine atomization (volume median diameters of less than 150 micrometers), improved formulation carriers that retard evaporation and protect the Bt, and increased knowledge and attention to application techniques and strategies (J.W. Barry, USDA Forest Service, private communication, 1992).

The objectives of the Charter orchard study were: to determine spray distribution pattern characteristics within and beneath the orchard canopy and the biological effectiveness of the Bt applications; to compare Kromekote card and straw sampling devices and assess the practicality and effectiveness of each in describing spray deposition patterns; and, to assess the amount of spray drift occurring from such a ULV spray operation (Roltsch et al., 1995). To meet these objectives, spray deposition data were taken within the orchard canopy and at ground level under the canopy, with sampling cards and soda straw samplers, and deposition of Bt was measured by assessing twig samples. Data were taken at two stages of flower and foliage: at the popcorn (bloom expansion) stage and the blossom petal fall stage, and samplers were placed throughout the orchard canopy. Accurate modeling of canopy effects is an important factor in the evaluation of field trials involving aerial application over forests, orchards, and other tree canopies. Biological data were also available, in the form of shoot strike counts assessed one month after the last application of Bt to the orchard.

The purpose of this report is to simulate drop deposition within the Charter orchard canopy on both the card and soda straw samplers, and to make an assessment of the

effectiveness of each type of sampler. Downwind drift is evaluated using data from cards and straws placed in untreated control areas. The Forest Service Cramer-Barry-Grim (FSCBG) aerial spray model (Teske et al., 1993b) is used to model the orchard canopy and predict the levels of deposition expected at the two stages of flower and foliage, and to predict downwind drift. Predicted levels of deposition are then compared to the card and soda straw deposit data throughout the canopy and to the ground card data. Biological data will also be discussed.

The FSCBG aerial spray model and its near-wake Agricultural Dispersal (AGDISP) model (Bilanin et al., 1989) have been developed by the USDA Forest Service in cooperation with the U.S. Army. FSCBG predicts the transport and behavior of sprays released from aircraft, influenced by the aircraft wake and local atmospheric conditions, through downwind drift and deposition to total accountancy and environmental fate. The AGDISP near-wake representation solves a Lagrangian system of equations for the position and position variance of material released from each nozzle on the spray aircraft. The FSCBG far-wake representation begins with the results of AGDISP at the top of a canopy or near the ground, and solves a Gaussian diffusion equation to recover canopy and ground deposition.

Technical aspects of the FSCBG model are discussed by Teske et al. (1993b). Previous comparisons with data are numerous and include a series of validation studies accomplished since 1993 (MacNichol and Teske, 1993a, 1993b, 1994a, 1994b, 1995). Studies which have used FSCBG canopy modeling capabilities for coniferous canopies include: MacNichol and Teske (1994b), Douglas-fir; Rafferty et al. (1982), Southern pine; and Teske et al. (1991), Douglas-fir. Several other studies have evaluated oak canopies: Anderson et al. (1992), eastern oak; Rafferty and Grim (1992), Gambel oak; and Teske, Barry and Rafferty (1994), Gambel oak. Broadleaf canopies have been previously modeled with FSCBG by Teske et al. (1993a), MacNichol (1996a and 1996b), and MacNichol and Teske (1996).

2. Field Trials Summary

2.1 Scope of the Field Trials

In early 1992 an aerial spray study consisting of two field trials was conducted in the Charter almond orchard in Arbuckle, California, in Colusa County. The study was a cooperative effort among grower Ray Charter, the University of California (U.C. Davis and the U.C. extension in Colusa), duPont, Entotech, Inc. and the USDA Forest Service. Two field trials took place on February 25 and March 3, and were designed to represent two stages of tree foliage, popcorn (initial flower bud expansion) and blossom petal fall. Since one objective of this study was to evaluate the effectiveness of the biopesticide *Bacillus thuringiensis* (Bt) in controlling peach twig borer, the spray material used was a NOVO insecticide with Bt as its active ingredient.

The study was limited to two replicates and two control blocks each day because of California State experimental use permit size restrictions issued for the unregistered Bt formulation used in the study. One ten-minute aerial application of Bt was sprayed on February 25 when the foliage was in its popcorn (bloom expansion) stage and repeated on March 3 when the foliage was in its blossom petal fall stage. The scope of the field trials is summarized in Table 1; the trials are described in detail in Roltsch et al. (1995). Note that both trials represent ultra low volume (ULV) Bt treatments applied at the same rate with a fixed-wing airplane and Micronair AU5000 rotary atomizers.

2.2 Spray Site

Orchard characteristics at the time of the field trials are given in Table 2. The orchard was established in 1976 and consisted of almond trees spaced on 7.3 meter centers that had not yet reached maturity. The average tree height was 6.1 meters, and average tree diameter at mid-canopy was 3.6 meters. For the purposes of the FSCBG simulation, the entire orchard was assumed to be uniformly distributed during each stage of foliage. The tree envelope used in the FSCBG canopy model is based on a typical broadleaf tree (Newton, 1987), and is shown in Table 2.

The orchard was divided into 4 adjacent blocks situated side-by-side in an east-west direction, two treated replicates and two control blocks, as shown in Figure 1. Each treatment block was 8.1 acres in size; unsprayed control blocks and treatment blocks were alternated as shown in Figure 1. Treatment blocks consisted of 15 rows of trees running north-to-south, and control blocks of 20 rows; each row in a block was approximately 320 meters in length. As is apparent from the tree envelope given in Table 2, trees did not touch between rows.

Sample trees were identified along three lines traversing the treatment blocks and perpendicular to the aircraft flight paths. There were 18 sampling positions along each line, for a total of 54 positions (each position represents a sample tree). Sample positions were spaced 14.6 meters apart (every other tree along the line was a sample tree). Only 8 positions on each of the lines were actually in treatment blocks; the remaining 10 sampling positions on each line were outside the blocks and are used to evaluate spray drift.

For each position (tree), card and soda straw samplers were placed at two canopy heights (2.7 meters and 4.0 meters), on the east and west sides of the sample tree. Figure 2 shows the sampler positions around each sample tree. A total of 216 Kromekote card samplers and 216 polyethylene soda straw samplers were placed in the canopy in each block. The cards measured 8 centimeters by 11 centimeters, and the soda straws measured 0.48 centimeters in diameter and 20 centimeters in length. Cards and straws were mounted horizontally on PVC poles extended upright into the outer canopy on the east and west sides of each sample tree, as shown in Figure 2.

An additional 108 Kromekote cards were placed on the ground, on either side of the sample trees.

2.2 Meteorological Measurements

Basic weather data were observed and recorded during the trials by USDA Forest Service personnel stationed at the ends of rows, using hand-held weather instruments. The data recorded are shown in Table 3. Hourly data are also available from a nearby weather station that supported IPM (Integrated Pest Management), and are consistent with the data recorded at Charter orchard; these data are also shown in Table 3. Spray times (shown in Table 1) ranged in duration from 4 to 5 minutes per treatment block, for total spraying times of 9 minutes for trial 1 (February 25) and 8 minutes for trial 2 (March 3). Both trials were conducted in the early afternoon (between 12:40 and 1:40PM).

2.3 Aircraft and Spray System

Table 4 summarizes the fixed-wing aircraft used in each of the Charter trials and its spray system: an Ag Cat, with six Micronair AU5000 rotary atomizers at 50 degree blade angle placed along a microfoil boom. The airplane flew at 49.2 m/sec, and the spray release height above the mean canopy top varied during each trial as shown in Table 4. Spray was applied at 0.5 gal/acre (ULV). The material sprayed was NOVO Biobit XL, with 0.1% Rhodamine WT liquid dye.

The spraying aircraft flew multiple passes over the blocks, in 14.6 meter swaths, north-to-south or south-to-north, centered on every other aisle. Flight lines were marked by vehicle during the trials. Figure 1 shows the flight lines for the two trials. Eight swath widths were flown over each treated block, and the control blocks were left unsprayed.

2.4 Data Reduction Procedure

The Kromekote cards and soda straws were positioned prior to spraying and were retrieved immediately after each application. Cards and straws were both assessed visually by counting and measuring drop stain diameters. Droplet stain marks were counted on a 4 cm^2 area on each card, and on a 5-centimeter long portion at the end of each straw. Drop deposition data (in drops per square centimeter) were generated for each card and straw. Field test data are tabulated in the Appendix.

After the February 25 trial, deposition of Bt was measured by determining colony forming units (CFUs) of the Bt spore based on twig samples. Four twigs were removed from the upper canopy of each of the sample trees immediately following treatment. A 3.8-centimeter section of each twig was removed. All four twigs from a given sample tree were then washed in sterile water and shaken, then diluted with sterile water (Roltsch et al., 1995). A portion of each dilution (0.1 ml) was plated out onto nutrient broth agar plates, and colonies were counted after 24 hours of incubation at 30 degrees C.

One bioassay method for peach twig borer is assessment of shoot strikes to determine larval activity; thus, biological data were collected as number of shoot strikes per block. The number of peach twig borer strikes in eight consecutive trees in three of the rows in each block were assessed visually on April 8, 1992. Six treated rows (three in each treated block) and six untreated rows were sampled.

2.5 Aircraft Characterization Trials

On February 13, 1992, a test was conducted to characterize the aircraft and spray system used in the Charter orchard trials. The same aircraft (an Ag Cat Super B) and spray system (6 Micronair AU5000 rotary atomizers) were flown over a line of 20 card samplers placed in open, flat terrain. The line was 58 meters long and was placed in an east-west direction. The aircraft flew in a north-south direction approximately over the center of the card line, directly into the wind, at a height of 6 to 9 meters (20 to 30 feet) above the ground. The wind speed at the time of the characterization trials was recorded as 2.7 to 4.0 m/s (6 to 9 mph). No other meteorological data were recorded. The same formulation was sprayed for the aircraft characterization trials and for the two Charter orchard trials described in this report.

The aircraft made four passes over the card line. The cards were then assessed for drop stains, and drop deposition data were generated. Deposition data are available in drops per square centimeter and in ounces per acre and will be discussed in section 4 of this report.

Table 1: Scope of the 1992 Charter Study

Trial	Block #	Treatment	Acres	Spray Start Time	Spray Finish Time
February 25, 1992	1	Treated[1]	8.1	12:40	12:45
(Popcorn stage)	2	Control	11.6	--	--
	3	Treated	8.1	12:46	12:50
	4	Control	11.6	--	--
March 3, 1992	5	Treated	8.1	13:28	13:32
(Petal fall stage)	6	Control	11.6	--	--
	7	Treated	8.1	13:34	13:38
	8	Control	11.6	--	--

1. Treatment was the same for both trials: undiluted Bt with Rhodamine WT liquid dye at 0.1%, sprayed at 0.5 gallons/acre. The Bt was Novo Biobit XL. Control blocks were not sprayed.

The same aircraft and spray system were used for both trials: an Ag Cat Super B 26Z equipped with six Micronair AU5000 rotary atomizers set at blade angle of 50 degrees.

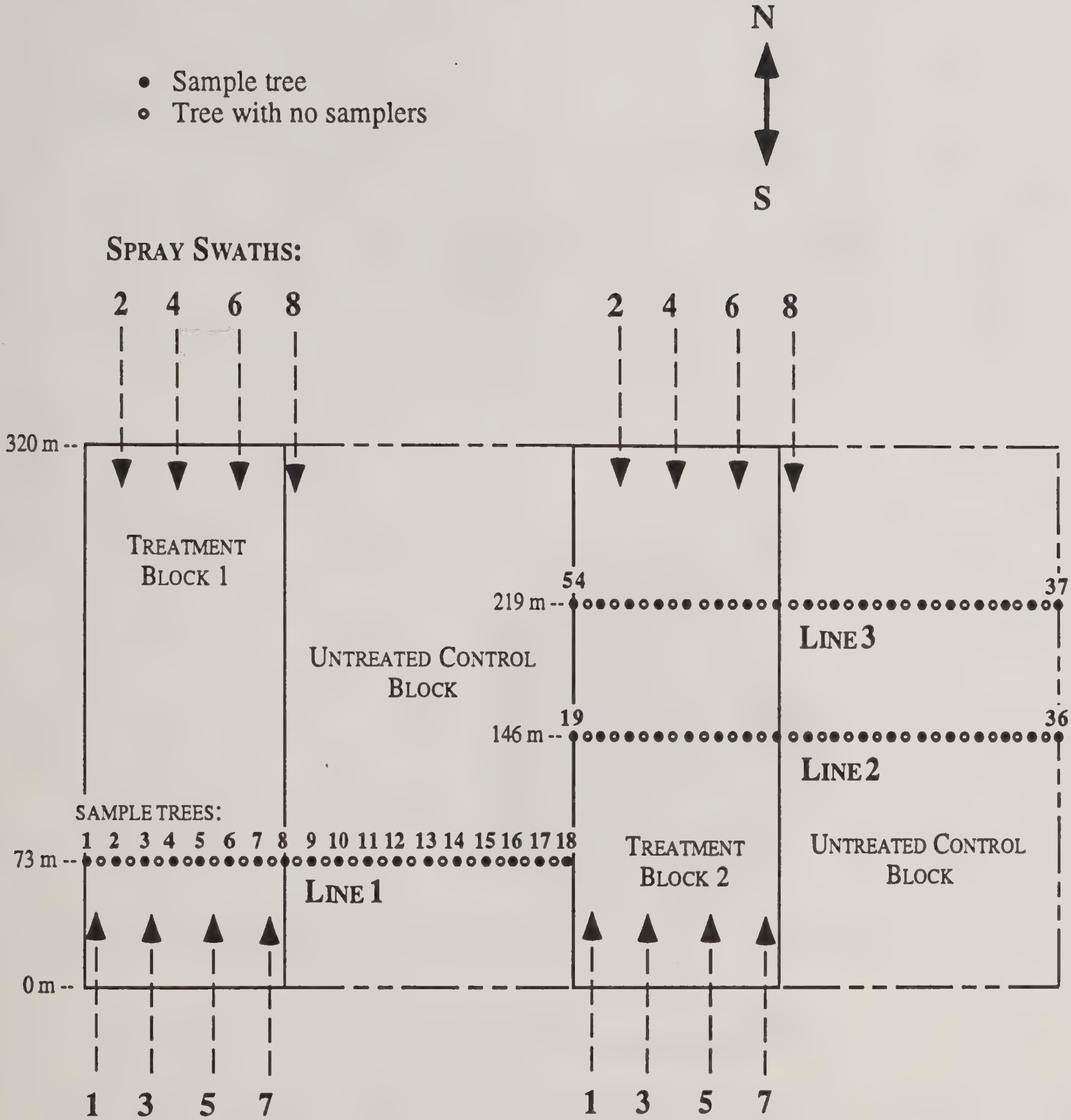
Table 2: Charter Almond Orchard Characteristics

Mean Canopy Height (m)	6.1
Tree Separation, center-to-center (m)	7.3
Stand Density	81 stems/acre
Tree Stage	Popcorn (Feb)[1] Blossom Petal Fall (Mar)[1]
Maximum Crown Diameter (m)	3.7

TREE ENVELOPE

Height (m)	Diameter (m)
0.2	0.3
0.6	0.3
1.2	0.3
1.8	2.7
3.0	3.7
4.3	3.6
4.9	3.5
6.1	2.4

1. These are bloom stages; popcorn refers to initial bloom expansion.

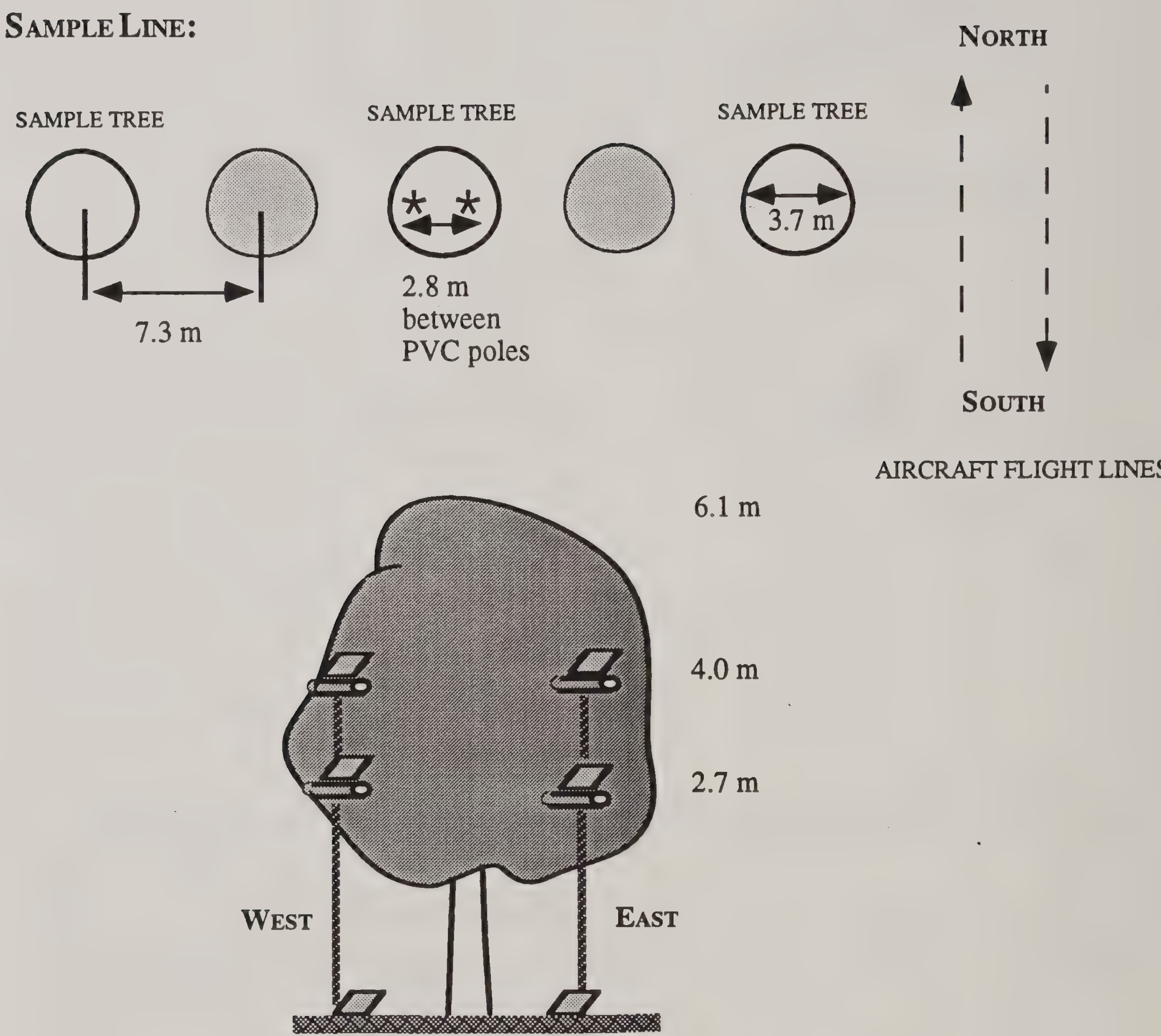


- Treated blocks were 320m by 102m; untreated blocks were 320m by 146m.

- Trees were separated by 7.3m. Every other tree was a sample tree.

- Line 1 was 73m north of the southern edge of Block 1.
- Line 2 was 146m north of the southern edge of Block 2.
- Line 3 was 219m north of the southern edge of Block 2.

Figure 1: Schematic of Charter Orchard (Colusa County, CA) showing the layout of sample trees, treated blocks and untreated control blocks for the 1992 trials.



- Mean canopy height was 6.1 meters.
- Trees were 3.7 meters in diameter at their widest point.
- Every other tree in a sample line was a sample tree; each line had 35 trees, 18 of them sample trees.
- There were 4 card samplers and 4 soda straw samplers placed in each tree, two at 2.7 m and two at 4.0 m. There were also 2 card samplers placed on the ground.
- Samplers were 1.4 m from the tree centerline.

Figure 2: Placement of sample trees and card and straw samplers in Charter orchard for the 1992 trials.

Table 3: Meteorological Data Recorded During the Charter Trials

Date	Time of Day	Temperature (deg. C)	Wind Speed (m/s)	Wind Dir. (deg[1])	RH (%)
February 25:					
Field Data[2]	12:40	17.8	1.3	320	65[4]
IPM Data[3]	12:00	18.0	1.3	210	65
	13:00	20.0	1.1	245	58
March 3:					
Field Data	13:28	--	2.2 to 2.7	164	--[5]
IPM Data	13:00	18.0	3.7	165	60
	14:00	18.0	3.9	164	59

1. Wind direction was measured in degrees from magnetic North.

2. These data were recorded at the test site by USDA Forest Service personnel using hand-held weather instruments. NA signifies that no measurement was recorded.

3. These data were recorded at a nearby weather station supporting University of California, Integrated Pest Management (IPM).

4. Relative humidity for trial 1 is calculated from wet and dry bulb temperature readings recorded on the field data sheets.

5. No temperature readings were recorded on field data sheets for trial 2.

Table 4: Aircraft and Spray System for the Trials

	BOTH TRIALS	
Aircraft	Ag Cat Super B 26Z	
Application Speed	49.2 m/s (110 mph)	
Swath Width	14.6 meters (48 feet)	
Spray System	6 Micronair AU5000 rotary atomizers at 50 degree blade angle	
Tank Mix	NOVO Biobit XL (Bt) with 0.1% Rhodamine WT liquid dye	
Application Rate	4.68 l/ha (0.5 gal/acre)	
Release Height (above canopy)	Trial 1 3.0 to 4.5 meters (10 to 15 feet)	Trial 2 4.5 to 6.0 meters (15 to 20 feet)

Trial 1 was conducted on February 25, 1992. Trial 2 was conducted on March 3, 1992.

3. Evaluation of Data From the Field Trials

The treated blocks of sample trees in the Charter orchard were identical in size and placed as shown in Figure 1, and the spraying aircraft flew evenly spaced swaths. The Charter orchard trees were typical of a young almond orchard (J.W. Barry, private communication, 1992). The mean canopy height at the time of the trials was 6.1 meters, and although trees were spaced 7.3 meters apart the maximum crown diameter was 3.7 meters (Table 2). The release height over the canopy varied during spray application (Table 4). In order to assess the overall deposition pattern in the orchard for each day of spraying, data are first presented by sample line. Sampler positions on the east and west sides of each sample tree are identified separately to indicate the amount of scatter in deposition around each tree.

During the following discussion of field test data, trial 1 refers to the treatment applied on February 25 (in the popcorn stage of foliage), and trial 2 refers to the treatment applied on March 3 (at blossom petal fall).

Figures 3 and 4 show card deposition data from trials 1 and 2 by sample line, at ground level. Data are plotted along an x-axis which indicates distance (in meters) from the west edge of treatment block 1. The west sample position of tree 1 is at x=0 meters, and the west sample positions of trees 19 (line 2) and 54 (line 3) are at x=256 meters east of x=0 (see Figure 1). Data from the west sample positions of each tree are shown as striped bars, and data from the east sample positions are shown as solid bars. The bold dashed vertical line at 250 meters marks the west edge of the second treatment area (treatment block 2 in Figure 1). The first and last spray swath over each sample line are shown by solid arrows. Card deposition data collected at 2.7 meters are shown in this same format in Figures 5 and 6 for trials 1 and 2, respectively. Card deposition data collected at 4.0 meters are shown in Figures 7 and 8 for trials 1 and 2, respectively. Several trends in the field data can be identified.

The most obvious trend in all of the data shown in Figures 3 through 8 is the sudden decrease in drop deposition at the eastern (downwind) edges of the treatment areas (approximately 120 m for treatment block 1 and approximately 375 m for treatment block 2) and minimal deposition in the untreated control blocks, indicating very little drift outside of the target areas. Drift will be discussed in detail in section 4 of this report.

There was significant deposition on the ground beneath the canopy in both trials, indicating that, as expected, the canopy did not capture all of the spray in either stage of foliage. There were fewer drops deposited on the ground during the petal fall stage of foliage (Figure 4) than during the popcorn stage (Figure 3).

Ground card deposition data shown in Figures 3 and 4 clearly indicate different deposition patterns for each of the three lines in the orchard. The difference in deposition from line to line is more pronounced in data from trial 1 (during which there was a 1.3 m/s wind from 320 degrees) than in data from trial 2 (during which there was a 2.7 m/s wind coming from 164 degrees). However, deposition patterns by sample line at the two canopy elevations (Figures 5 and 7) appear to be similar, despite considerable scatter in the data from either side of the sample trees and differences in overall levels of deposition observed at each elevation. This same observation can be made for the canopy card data from trial 2

(Figures 6 and 8). Furthermore, Roltsch et al. (1993) found that mean densities of spray droplets were very consistent on mid-canopy cards for both application treatments, even though there were considerable differences between within-tree droplet distribution.

Despite the gaps between trees in the orchard, the pattern of deposition throughout the canopy seems to be consistent for each treatment. Data from another almond orchard field study (MacNichol, 1996a) has shown that, for ULV application of the same formulation of Bt, the samplers around all trees experienced similar canopy effects at each elevation regardless of the area of the orchard in which they were found, and regardless of their position with respect to the tree centerline.

As mentioned, there is scatter in deposition data observed on either side of the sample trees. Roltsch et al. (1995) found that, statistically, there was less variability in spray distribution from east to west on the ground than in the canopy. They also note that significantly more droplets occurred on cards in the upper eastern region of each tree than in other locations within the tree, especially during trial 1. This trend is readily apparent in Figures 5 and 6. The solid bars in Figure 6 show the eastern card samplers at 4.0 meters, for trial 1. Deposition observed on those samplers was significantly higher than deposition observed on other cards within the trees in trial 1. Roltsch et al. (1995) noted that drop data from the straw samplers in the upper east canopy of trial 1 did not show the same trend, and concluded that the card sampler data may reflect a statistical aberration, demonstrating the need for numerous samplers (of either type) due to high droplet variability among sampling units.

In fact, the amount of scatter seen in the Charter orchard data is to be expected in field data of this type, particularly because of the large number of sampling units placed throughout the canopy (J.W. Barry, private communication, 1996 and MacNichol, 1996b).

FSCBG modeling assumes that the orchard canopy is uniformly distributed on each day of testing. Assuming a uniform canopy and uniform test conditions, data from all three lines of sample trees can be regarded as repetitions of one set of data, with 18 sample trees along the resulting line. This will be referred to as the reference sample line. Each of the trees has sampler positions east and west of its centerline, and at each position there are samplers placed at three elevations: ground level, 2.7 meters and 4.0 meters. Figure 9 shows the locations of sampler positions on the reference sample line. The westernmost position in a treatment block is arbitrarily assigned a location of 0 meters. Thus, the west sample position on trees 1, 19 and 54 (from lines 1, 2 and 3, respectively) is at 0 meters, and the east sample position on each of those trees is at 2.8 meters.

Tree positions 1 through 8 (0 to 105 meters) are in the treatment blocks and tree positions 9 through 18 (117 to 250 meters) are in the untreated control blocks. There are three sets of Kromekote card data for each tree (one at each elevation) and two sets of polyethylene straw data for each tree (one at 4.0 meters and one at 2.7 meters). Figures 10 and 11 show drop deposition on the ground for trials 1 and 2, respectively: tree position along the reference sample line is shown on the x-axis and deposition is shown on the y-axis. Figures 12 and 13 show drop deposition along the reference sample line for cards and straws, respectively, at 2.7 meters elevation for trial 1; Figures 14 and 15 show drop deposition for cards and straws, respectively, at 2.7 meters elevation for trial 2. Figures 16

(cards) and 17 (straws) show drop deposition data at 4.0 meters elevation for trial 1; Figures 18 (cards) and 19 (straws) show drop deposition data at 4.0 meters elevation for trial 2.

Figures 10 through 19 clearly show three of the trends already discussed: the sudden decrease in drop deposition at the edge of the treatment areas; the significant amount of ground deposition in treated areas during both trials; and the large degree of scatter in card data at specific locations along the reference sample line, at all elevations and for both trials. Indeed, the scatter in drop deposition data within the treatment blocks is now apparent for both types of samplers. There is no pattern to the amount of scatter observed throughout the canopy for each trial, other than the high droplet counts observed on cards in the upper eastern regions of the trees in trial 1 (as mentioned, this was a trend not observed in the straw deposition data). Roltsch et al. (1995) concluded that variability in the drop deposition data is locally high even within trees at specific vertical strata. However, there is a significant correlation between deposition on cards and straws from a given sample tree, and the absolute droplet densities on cards and straws compare closely in most instances (Roltsch et al., 1995). In other words, the scatter in deposition data is similar in magnitude for both types of collector. This observation suggests that the scatter may be due to nonuniformity of the canopy or to variable test conditions (possible variances in aircraft release height and micrometeorology) rather than to differences inherent in the collectors themselves.

Table 5 shows the mean drop deposition on cards and straws at each elevation in the canopy and the mean drop deposition on ground cards, for each of the three sample lines placed in the orchard for the two trials. Although it was previously mentioned that there was considerable scatter in drop deposition data from individual samplers (cards and straws) placed on the east and west sides of trees, there is generally good agreement between mean levels of deposition on either side of trees. Table 5 indicates that mean drop data observed on each sample line were more consistent at each elevation for trial 2 than for trial 1. For both trials, mean levels of drop deposition are highest at 4.0 meters for both types of samplers. The same observation has been made for other broadleaf canopies sprayed at similar stages of flower and foliage (Newton et al., 1989). More foliage is generally present in the top third of a canopy, providing more opportunity to impact, and more competition for the given number of drops. For these young almond trees, the aircraft wake likely provided impaction energy and increased turbulence in the upper canopy, further helping in canopy penetration and impaction (J.W. Barry, private communication, 1996).

The absolute level of drop deposition in each trial is considerably different, as previously observed. More drops were deposited on samplers at each elevation during trial 1 (popcorn stage of foliage) than during trial 2 (petal fall stage of foliage). This is true for both types of samplers, and is even true when comparing mean levels of deposition for each of the three sample lines placed in the orchard. Figure 20 shows a bar graph of the mean drop deposition in the canopy and on the ground for each of the two trials; data from both types of collectors are shown. The mean drop deposition observed on ground samplers was 45% lower for trial 2 than for trial 1. Mean drop deposition observed on card samplers in the canopy was 16% lower for trial 2, and mean drop deposition on straw samplers was 31% lower. Similar observations regarding mean deposition levels during each trial were made by Roltsch et al. (1995) during their statistical analysis of the field data.

Although Roltsch et al. (1995) and the study plan for the trials (J.W. Barry, private communication, 1992) refer to the canopy sampling elevations as "mid-canopy" (2.7

meters) and "upper canopy" (4.0 meters), the actual top of the canopy is at 6.1 meters. The distinction between the "top" of the canopy and the "upper" canopy is an important one. Ideally, the top of the canopy captures a portion of the spray, and what remains passes through the rest of the canopy and then to the ground; mass deposition occurs throughout the canopy and on the ground. Placing collectors below the canopy top and on the ground (as is the case for the Charter trials) will miss a portion of the spray depositing near the top of the canopy. Data from the 1980 Withlacoochee State Seed Orchard spray trials show that an average of 41% of the drops deposited in that pine canopy were found at the top of the crown (MacNichol, 1996c). Figure 20 actually shows deposition in the lower canopy (2.7 meters) and the mid-canopy (4.0 meters), and omits deposition at the top of the canopy (approximately 6.0 meters). To avoid confusion, the canopy sampling positions in the Charter trials will continue to be specified according to elevation (2.7 and 4.0 meters).

In a set of almond orchard spray trials previously simulated with FSCBG (the Hennigan Orchard trials, MacNichol, 1996b), also sprayed ULV at the same stages of flower and foliage as the Charter trees, mean levels of deposition (in drops per square centimeter) observed on samplers at mid-canopy were nearly equal to mean levels of deposition observed on the ground. The Hennigan orchard trees were mature trees, taller and much wider than the Charter trees. Nevertheless, the Charter field data presented here show the same trend: for both trials, the mean deposition observed on cards at mid-canopy (4.0 meters) is nearly the same as the mean level of deposition observed on the ground. For the mature Hennigan trees, mean levels of deposition observed in each stage canopy were approximately the same, while for the younger Charter trees mean levels of deposition observed during the first treatment (popcorn stage) were higher than mean levels observed during the second treatment (petal fall stage).

One reason that fewer drops were deposited on samplers during Charter trial 2 may have been that the greater presence of foliage during the petal fall stage combined with more turbulent meteorological conditions during spraying (see Table 3) resulted in more scavenging of drops by the lower canopy. During trial 1, conducted in the popcorn stage of foliage, only leaf tips and swelled flowering buds were present in the canopy, and meteorological conditions were quiescent. Drops would have encountered less obstruction when passing through this canopy than when passing through the denser foliage of the petal fall-stage canopy. More spray would have deposited on the canopy collectors, and penetrated to the ground samplers. Less of the spray would have been captured by the canopy. Figure 20 shows that mean deposition on the ground in trial 1 is the same as mean deposition at 4.0 meters, and much higher than mean deposition at 2.7 meters. The lower portions of the canopy in trial 1 seem to be nearly transparent to the spray, probably due to the large gaps between the young almond trees in the Charter orchard and the sparse foliage in the popcorn canopy.

Another reason that fewer drops were deposited on samplers during trial 2 may have been the difference in release heights for the two trials: during trial 1, release height varied from 3 to 4.5 meters above the canopy, and for trial 2 it varied from 4.5 to 6 meters above the canopy. The variation in release height during each of the trials may also account for some of the scatter in the field data: Teske and Barry (1993) found that, to maintain a 1% accuracy on deposition pattern and drift effects, the release height would have to vary by no more than 0.4%. In the Charter trials, release height varied by as much as 50% during spraying.

For trial 2 (during the petal fall stage of foliage), the mean deposition on cards at 2.7 meters and at ground level was essentially the same (10 drops per square centimeter), and deposition at 4.0 meters was only slightly higher (13 drops per square centimeter). The mid-canopy and lower canopy in the petal fall stage of foliage seems to have scavenged spray more evenly than the popcorn canopy of trial 1. Teske et al. (1993a) note that the additional vegetative elements in the almond trees in the petal fall stage of foliage could have influenced the turbulence level and resulting spray distribution within the canopy. The meteorological conditions during this trial were more turbulent than those during trial 1, and these could also have accounted for increased impaction.

Deposition data are also available as colony forming units (CFUs) of the Bt spore per 100ml of dilution, as described in section 2.4. These data relate to the level of deposition of Bt on elements of the tree (in this case, twigs), and are only available as average values for each sample tree along sample lines in trial 1. No CFU data were collected during trial 2. Although these data are not drop data, they do indicate deposition patterns for Bt, and thus for the spray formulation. Figure 21 compares the mean deposition in the canopy (east and west sample positions at both canopy elevations, by sample tree position along a single sample line) for the three types of sampling methods: card samplers (top); straw samplers (middle); and CFUs of Bt (bottom).

Roltsch et al. (1995) indicate that the variation among twig samples was large, and that there was no significant correlation between deposition as measured on a tree basis by droplets on cards versus CFUs (whereas good correlation was found to exist between droplets on cards and droplets on straws). However, the pattern of deposition shown in Figure 21 is very similar for all three sampling methods. Card sampler data points (shown at the top of Figure 21) in the treated portion of the reference sample line (from 0 to approximately 120 meters) were normalized by the average deposition on card samplers in the canopy over this same portion of the reference sample line. Straw sampler data and twig sample data were also normalized. Normalized card and straw sampler data are plotted against corresponding normalized twig sample data in Figure 22. Correlation of normalized canopy card and straw data to normalized twig sample data shows least squares slopes of 0.75 and 0.89, respectively, with $R^2 = 0.43$ for correlation of cards to twigs and $R^2 = 0.55$ for correlation of straws to twigs. Considering the amount of scatter in the deposition data shown in Figure 21, which is typical for this type of operational field test, all three methods of sampling deposition in the canopy give consistent results. Roltsch et al. (1995) note that twig sampling is an expensive technique for use on a large scale, and therefore seems unfeasible for use in assessing routine application techniques.

Biological data were gathered as described in section 2.4; however, they are not shown in this report. Roltsch et al. (1995) note that shoot strike counts were numerically lower in treated areas as compared to untreated areas. However, they also note that the actual level of damage, particularly in control areas, was probably greater than estimated, and that additional replication would provide better resolution of experimental results. They concluded that no statement on the biological efficacy of the Bt treatments is possible.

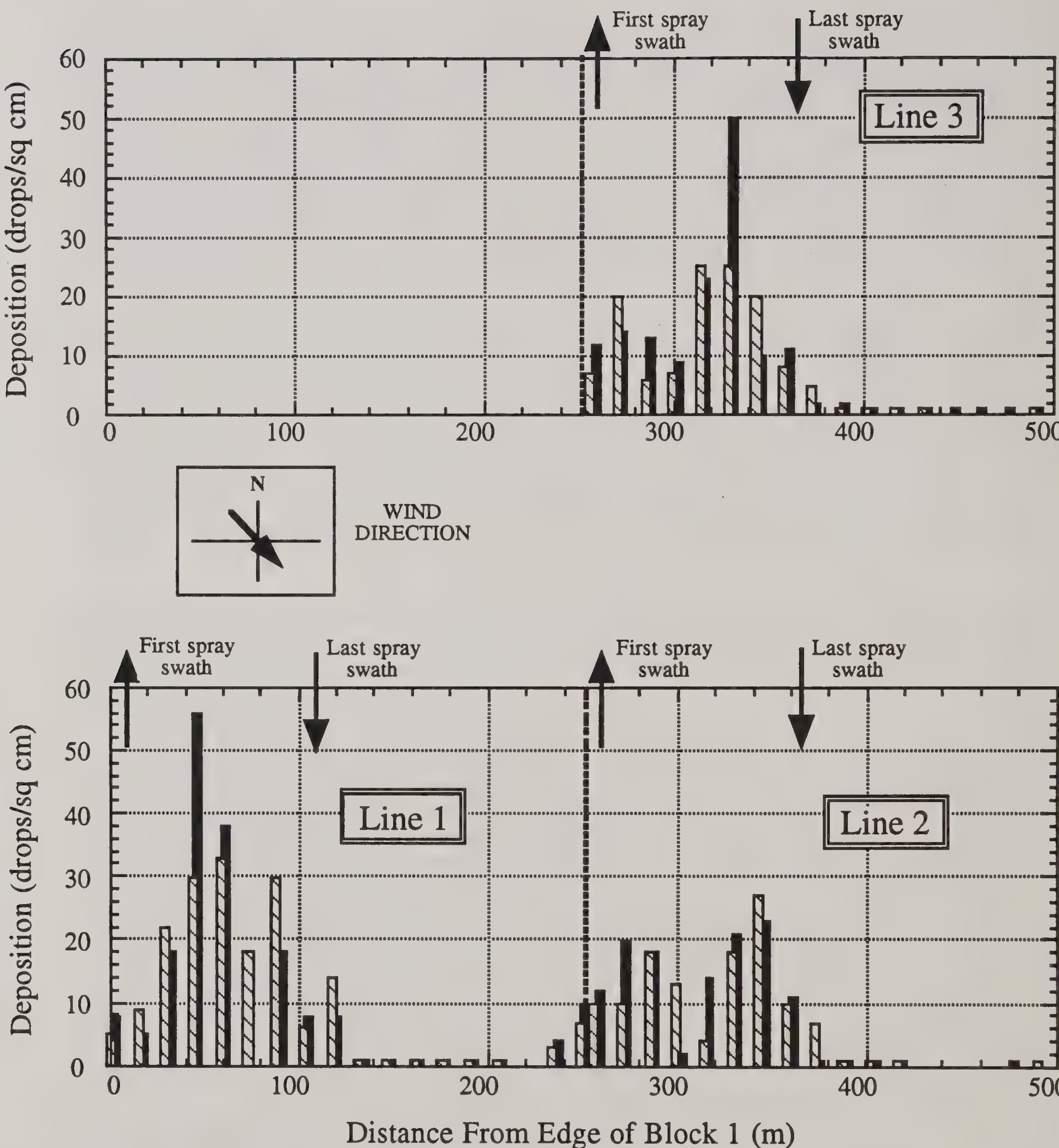


Figure 3: Trial 1, field test deposition on **ground** cards for sample lines 1, 2 and 3, in drops per square centimeter: line 3 (top) was 219m north of the southern edge of the treatment blocks; line 2 (bottom right) was 146m north; line 1 (bottom left) was 73m north. Wind direction was recorded as 320 degrees (as shown). Solid bars show data on the **east** side of sample trees; striped bars show data on the **west** side. The bold dashed line marks the western edge of treatment block 2 (256 meters).

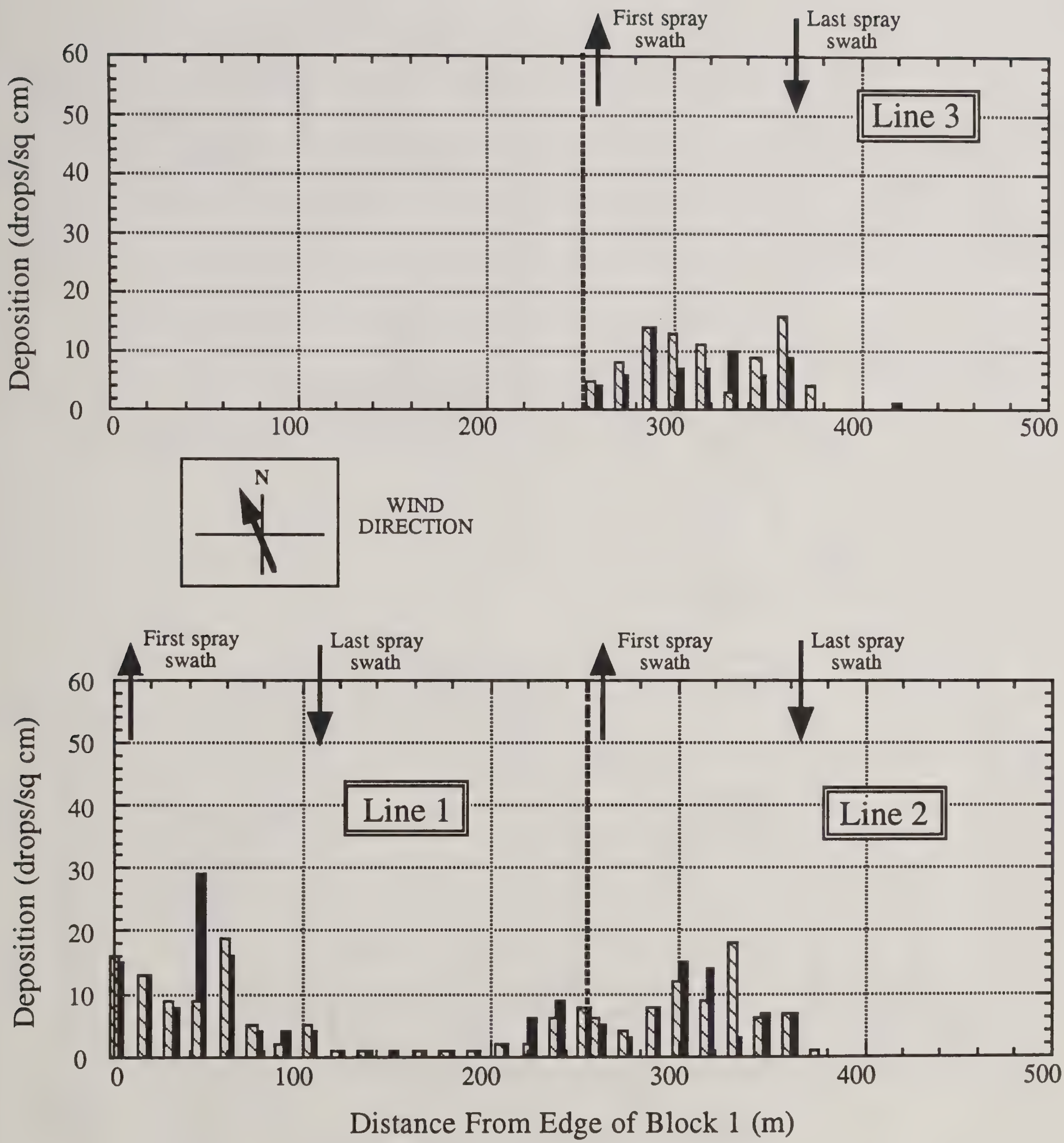


Figure 4: Trial 2, field test deposition on **ground** cards for sample lines 1, 2 and 3, in drops per square centimeter: line 3 (top) was 219m north of the southern edge of the treatment blocks; line 2 (bottom right) was 146m north; line 1 (bottom left) was 73m north. Wind direction was recorded as 164 degrees (as shown). Solid bars show data on the **east** side of sample trees; striped bars show data on the **west** side. The bold dashed line marks the western edge of treatment block 2 (250 meters).

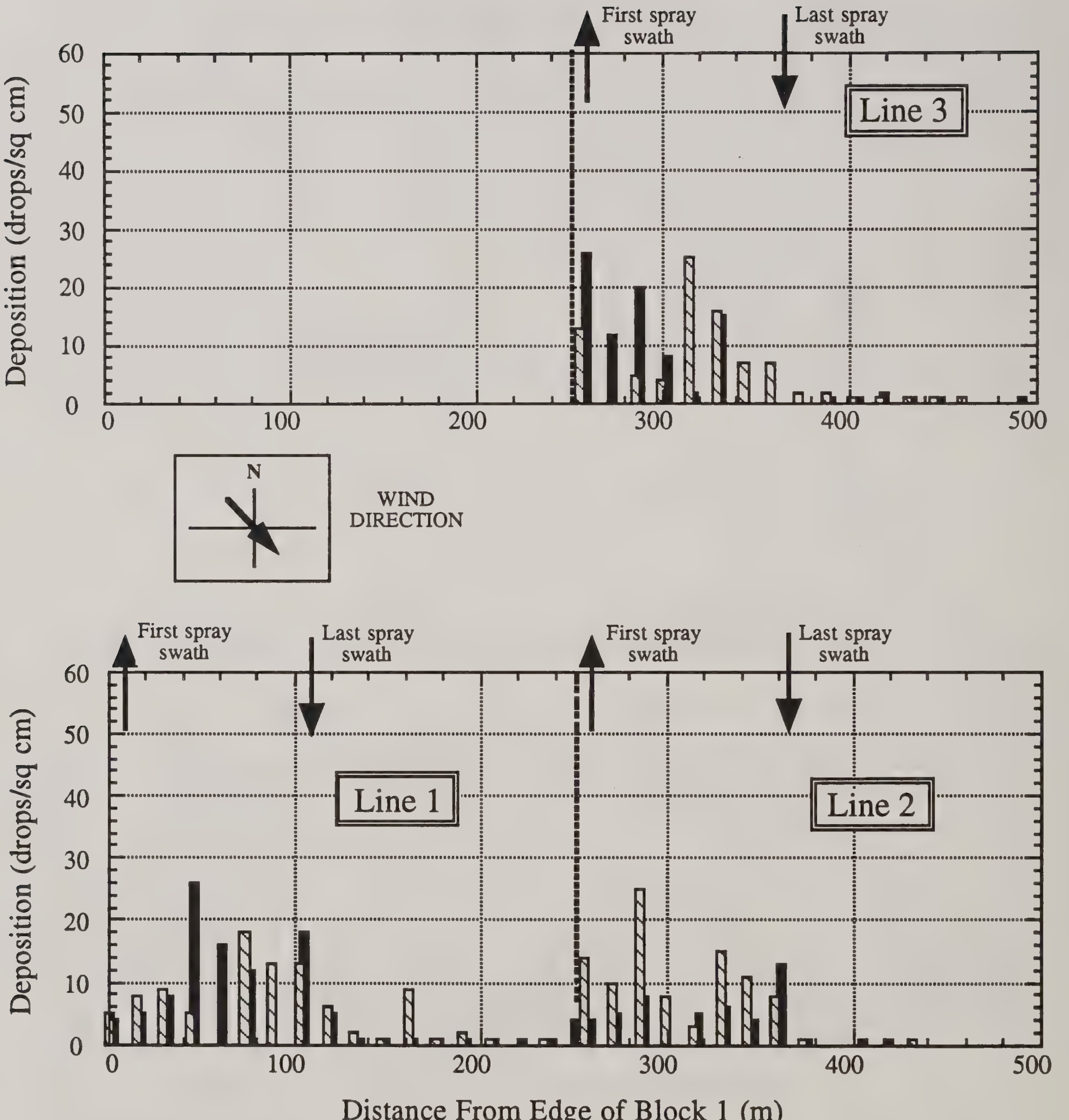


Figure 5: Trial 1, field test deposition on cards **2.7-meter** above ground, for sample lines 1, 2 and 3, in drops per square centimeter: line 3 (top) was 219m north of the southern edge of the treatment blocks; line 2 (bottom right) was 146m north; line 1 (bottom left) was 73m north. Wind direction was recorded as 320 degrees (as shown). Solid bars show data on the **east** side of sample trees; striped bars show data on the **west** side. The bold dashed line marks the western edge of treatment block 2 (256 meters).

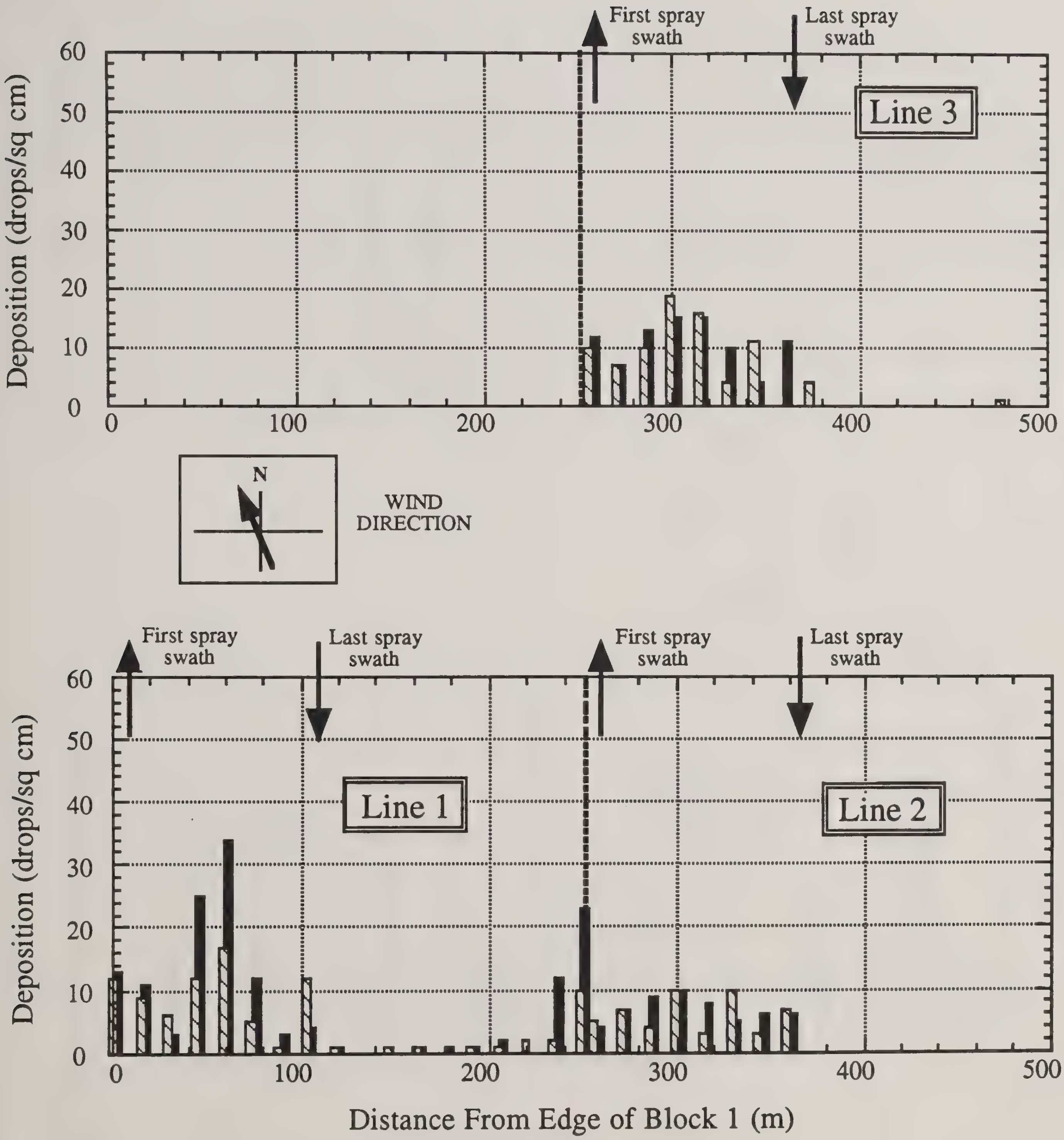


Figure 6: Trial 2, field test deposition on cards **2.7-meter** above ground, for sample lines 1, 2 and 3, in drops per square centimeter: line 3 (top) was 219m north of the southern edge of the treatment blocks; line 2 (bottom right) was 146m north; line 1 (bottom left) was 73m north. Wind direction was recorded as 164 degrees (as shown). Solid bars show data on the **east** side of sample trees; striped bars show data on the **west** side. The bold dashed line marks the western edge of treatment block 2 (256 meters).

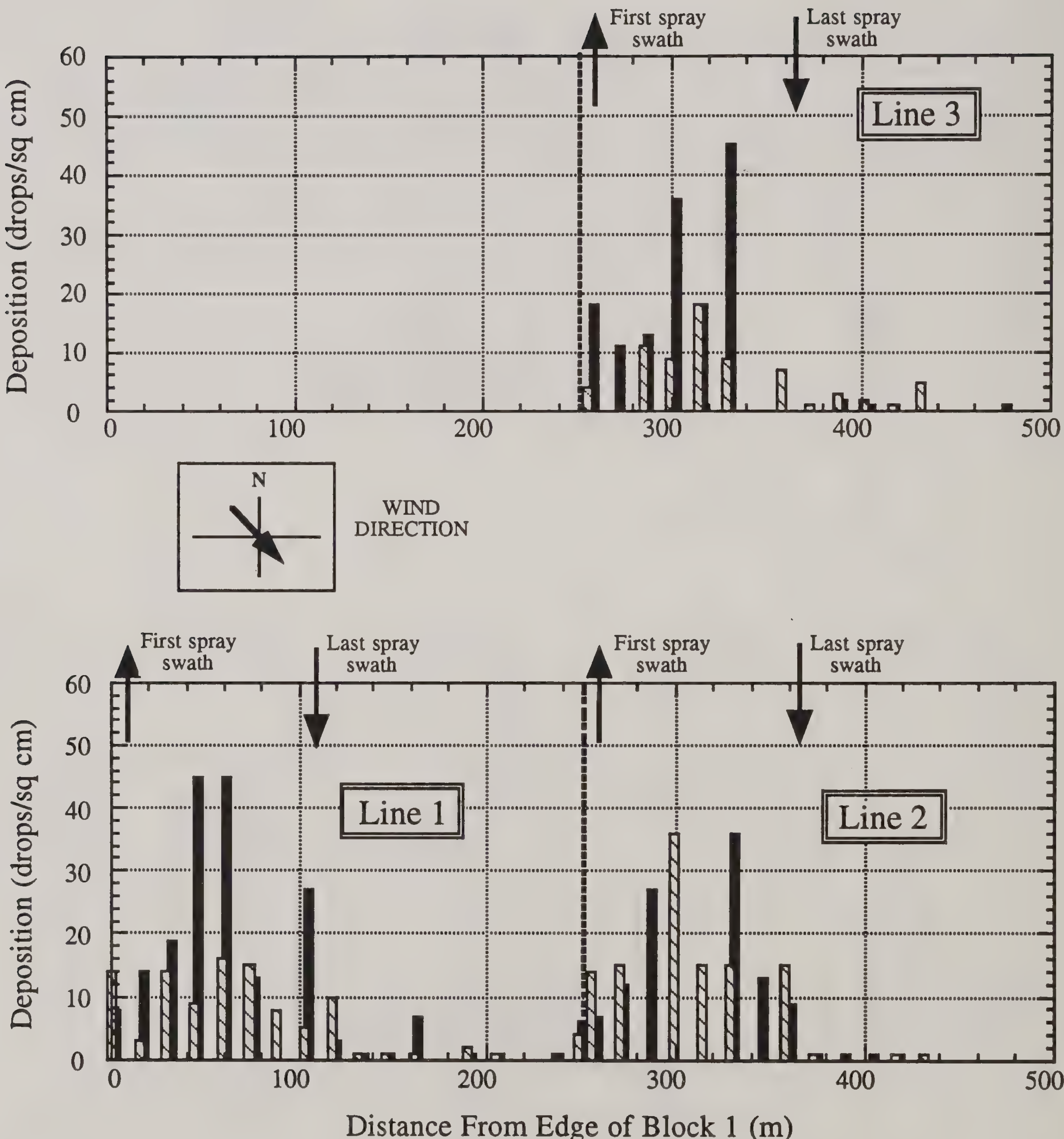


Figure 7: Trial 1, field test deposition on cards **4.0-meter** above ground, for sample lines 1, 2 and 3, in drops per square centimeter: line 3 (top) was 219m north of the southern edge of the treatment blocks; line 2 (bottom right) was 146m north; line 1 (bottom left) was 73m north. Wind direction was recorded as 320 degrees (as shown). Solid bars show data on the **east** side of sample trees; striped bars show data on the **west** side. The bold dashed line marks the western edge of treatment block 2 (256 meters).

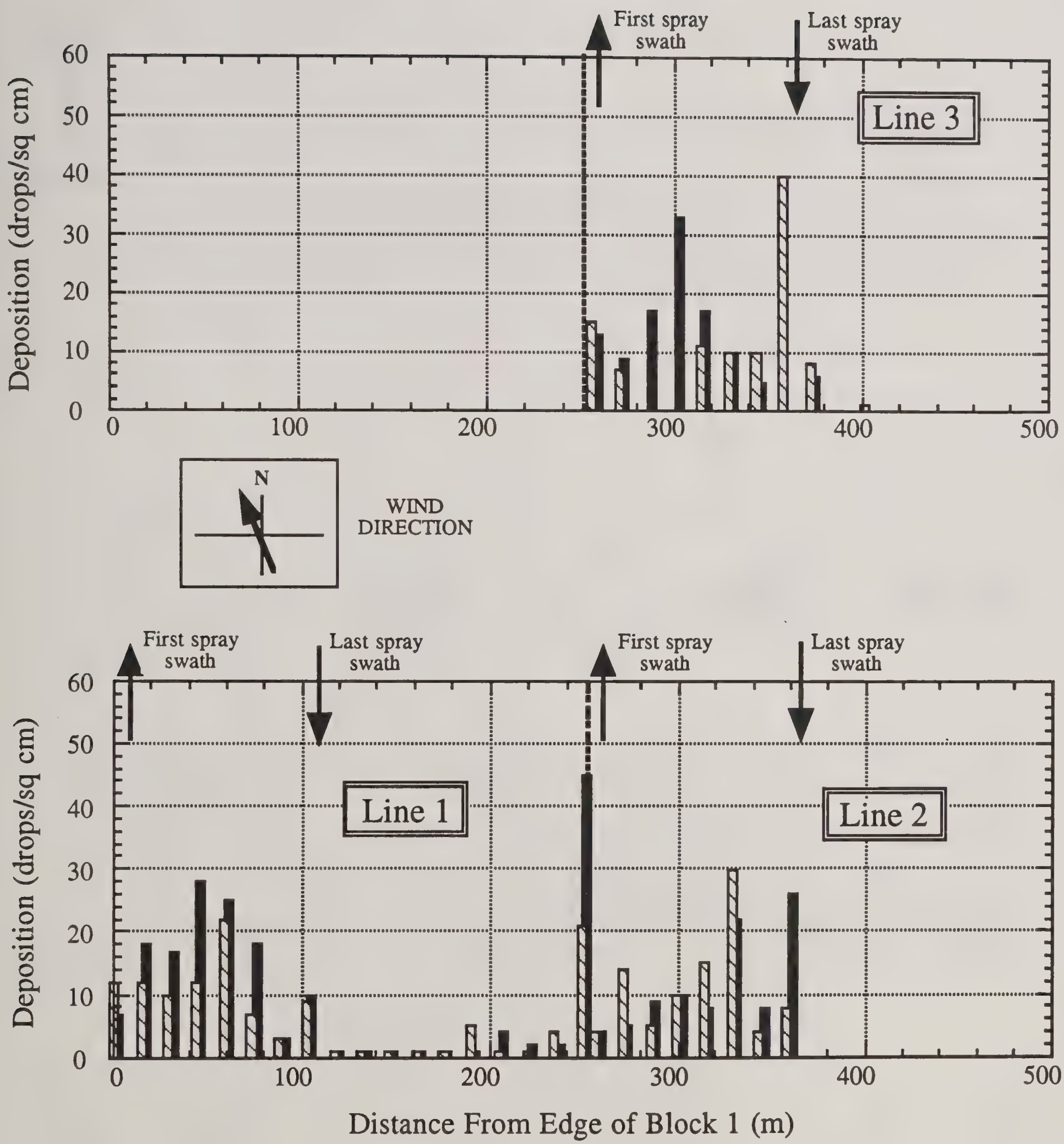


Figure 8: Trial 2, field test deposition on cards **4.0-meter** above ground, for sample lines 1, 2, and 3, in drops per square centimeter: line 3 (top) was 219m north of the southern edge of the treatment blocks; line 2 (bottom right) was 146m north; line 1 (bottom left) was 73m north. Wind direction was recorded as 164 degrees (as shown). Solid bars show data on the **east** side of sample trees; striped bars show data on the **west** side. The bold dashed line marks the western edge of treatment block 2 (256 meters).

POSITIONS FOR SAMPLE TREES:

For the purposes of plotting field deposition, all three lines of sample trees are presented along the x-axis, with positions assigned as shown. Each sample tree has two samplers (a card and a straw) at two elevations on PVC poles **EAST** of its centerline and **WEST** of its centerline, and a card on each side at ground level.

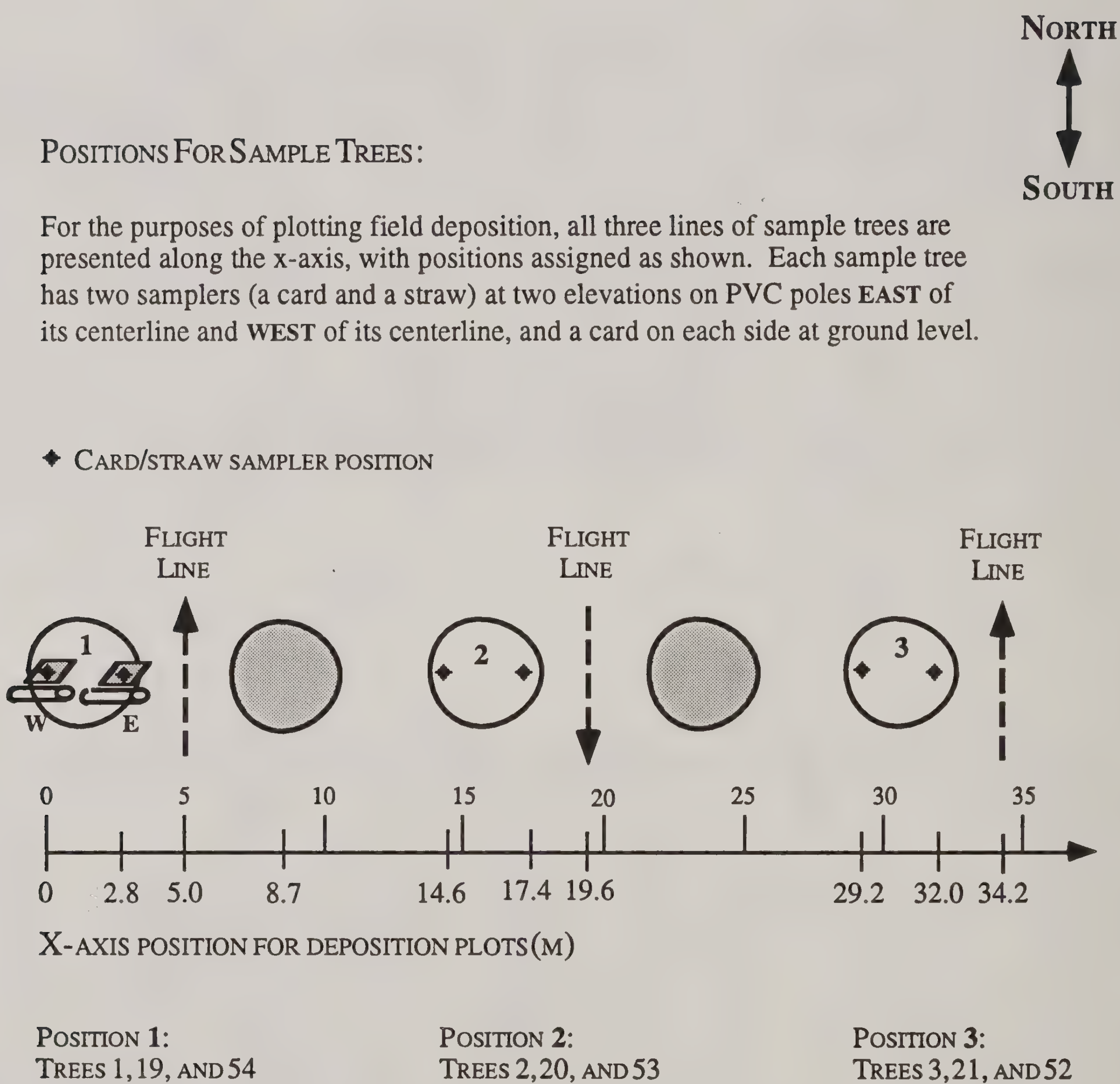


Figure 9: Tree positions for presentation of field test data.

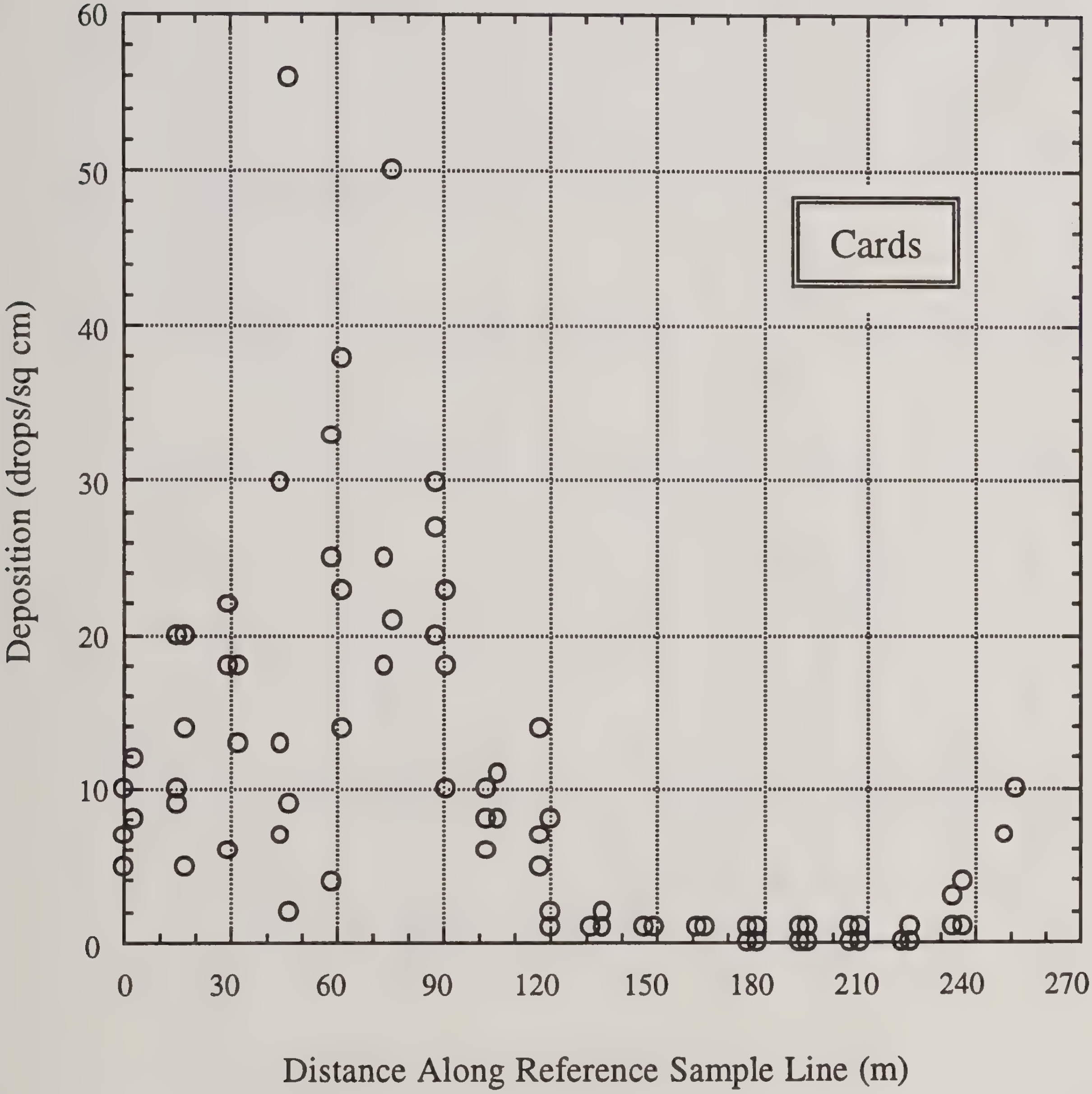


Figure 10: Charter orchard trial 1, field test deposition in drops per square centimeter for all **ground** cards, shown along a reference sample line. Mean observed deposition for trial 1 ground cards = 17 drops/sq cm.

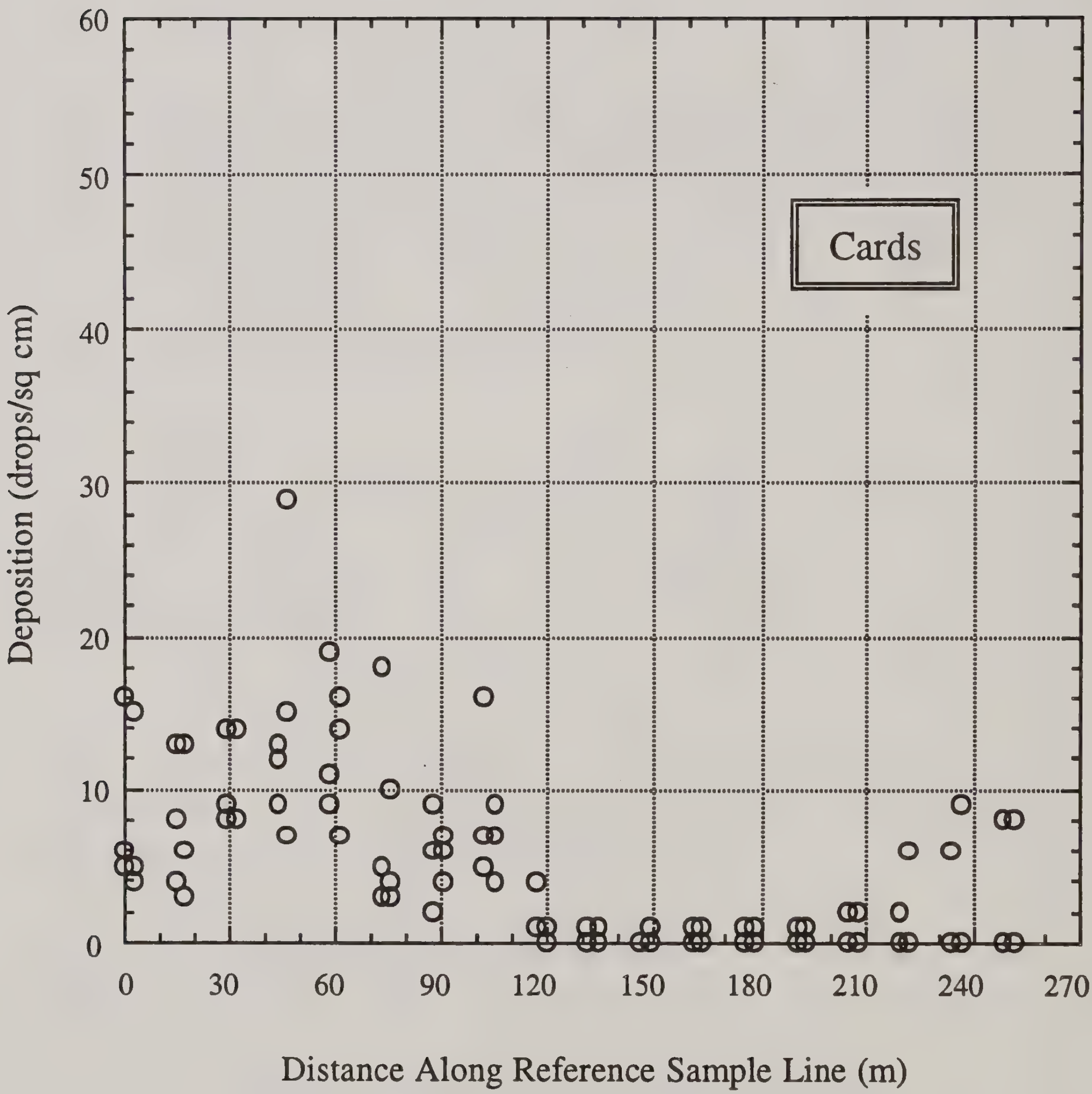


Figure 11: Charter orchard trial 2, field test deposition in drops per square centimeter for all **ground** cards, shown along a reference sample line. Mean observed deposition for trial 2 ground cards = 10 drops/sq cm.

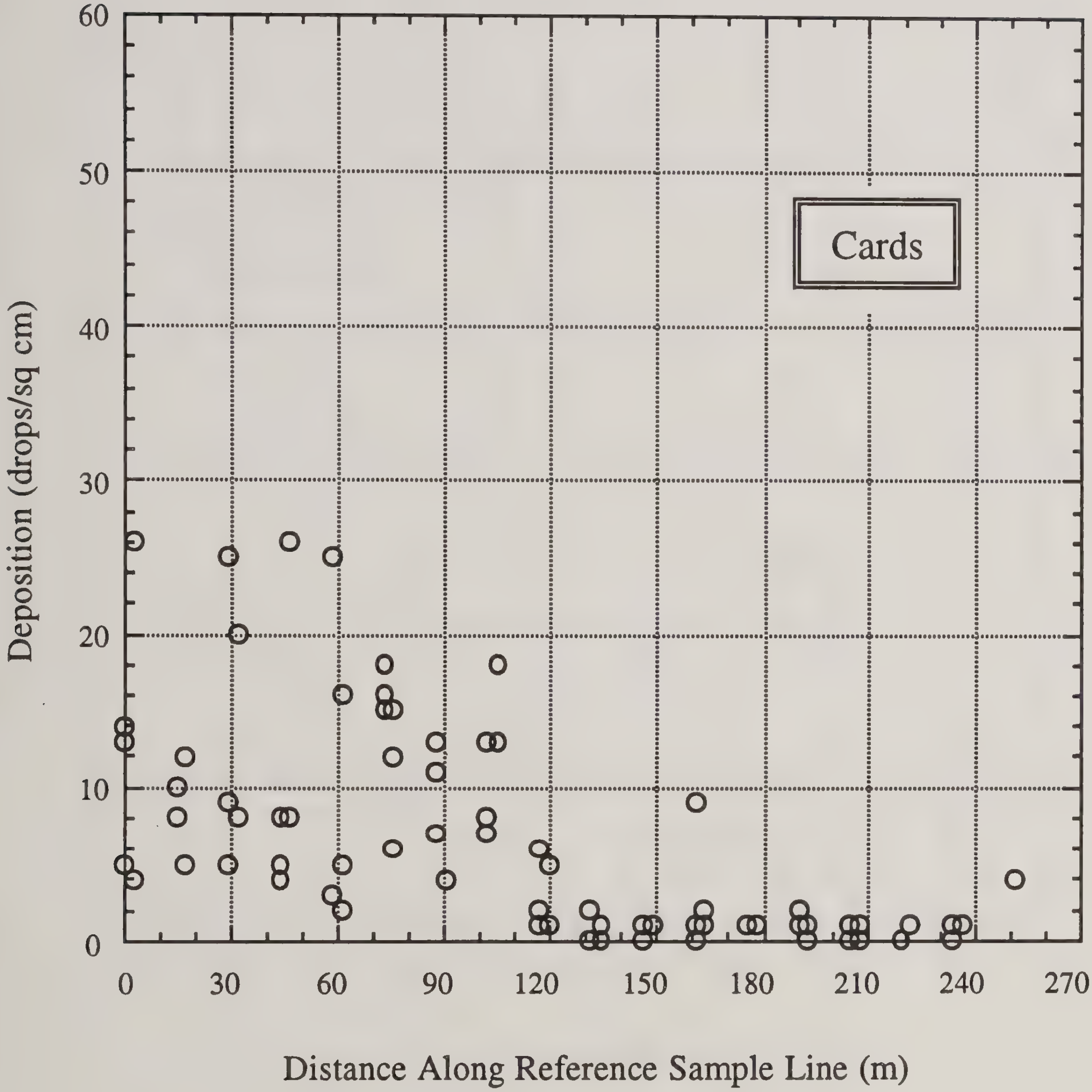


Figure 12: Charter orchard trial 1, field test deposition in drops per square centimeter for all **2.7-meter** elevation cards, shown along a reference sample line. Mean observed deposition for trial 1, 2.7 meter elevation cards = 11 drops/sq cm.

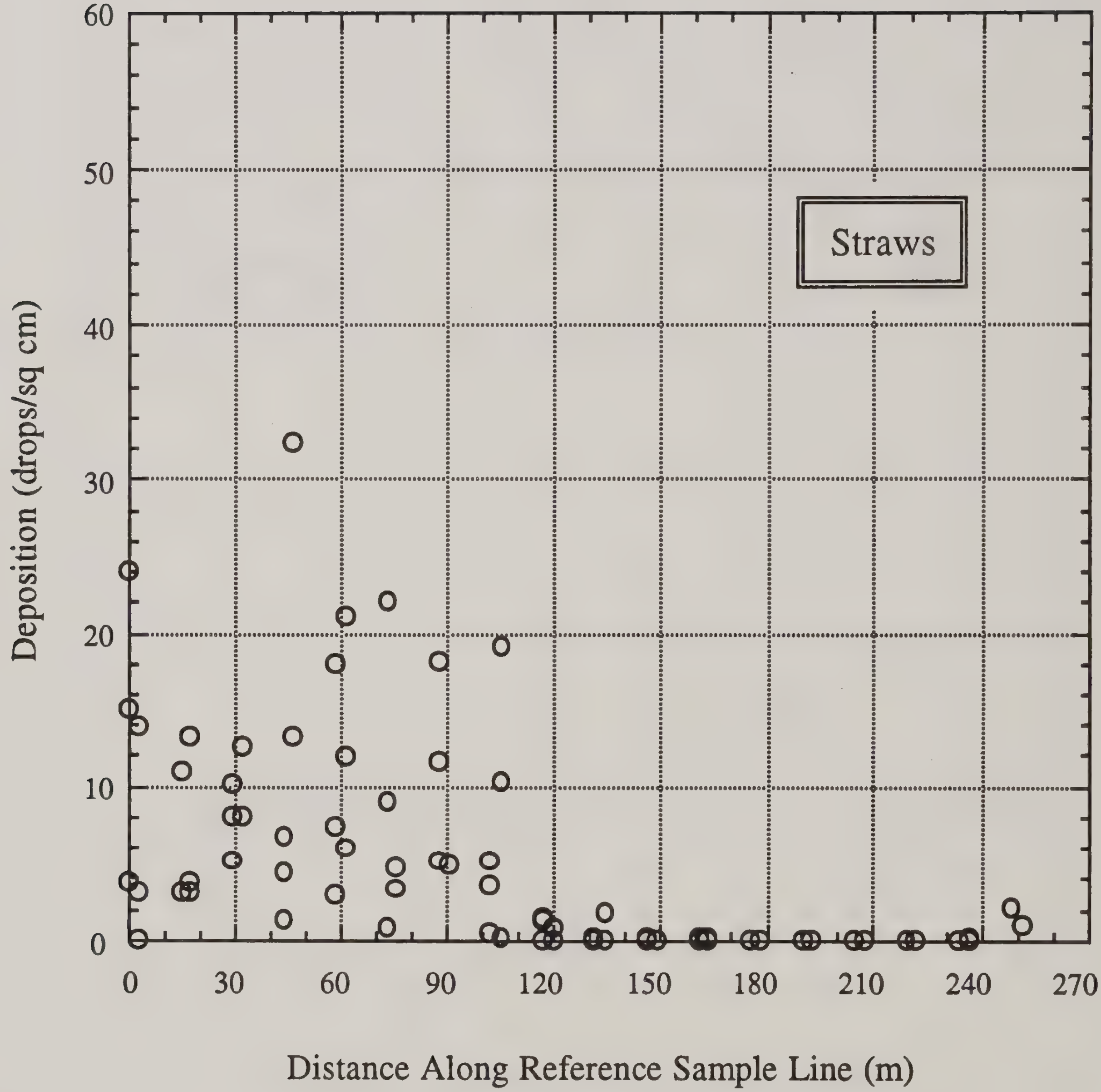


Figure 13: Charter orchard trial 1, field test deposition in drops per square centimeter for all **2.7-meter** elevation straws, shown along a reference sample line. Mean observed deposition for trial 1, 2.7 meter elevation straws = 10 drops/sq cm.

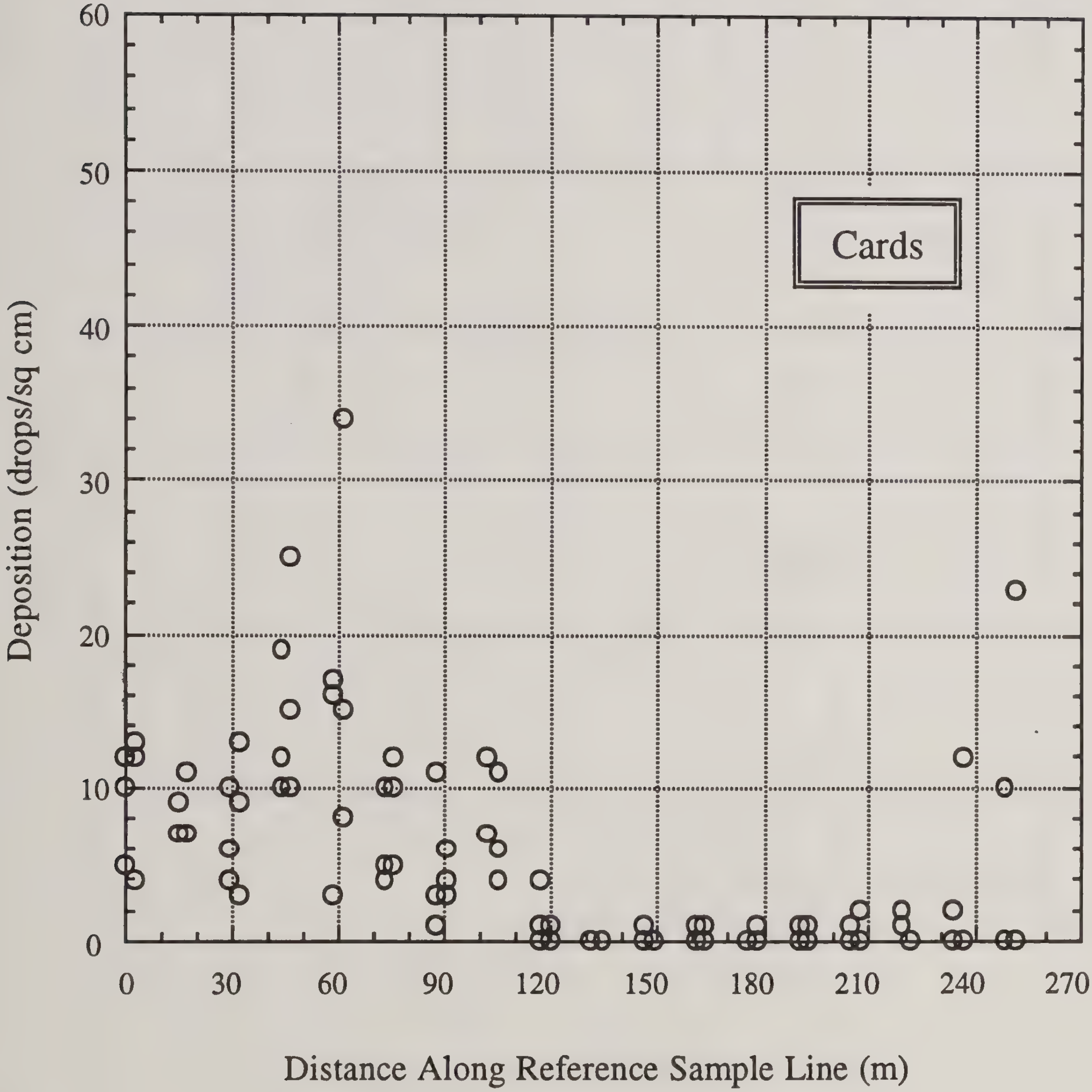


Figure 14: Charter orchard trial 2, field test deposition in drops per square centimeter for all **2.7-meter** elevation cards, shown along a reference sample line. Mean observed deposition for trial 2, 2.7 meter elevation cards = 10 drops/sq cm.

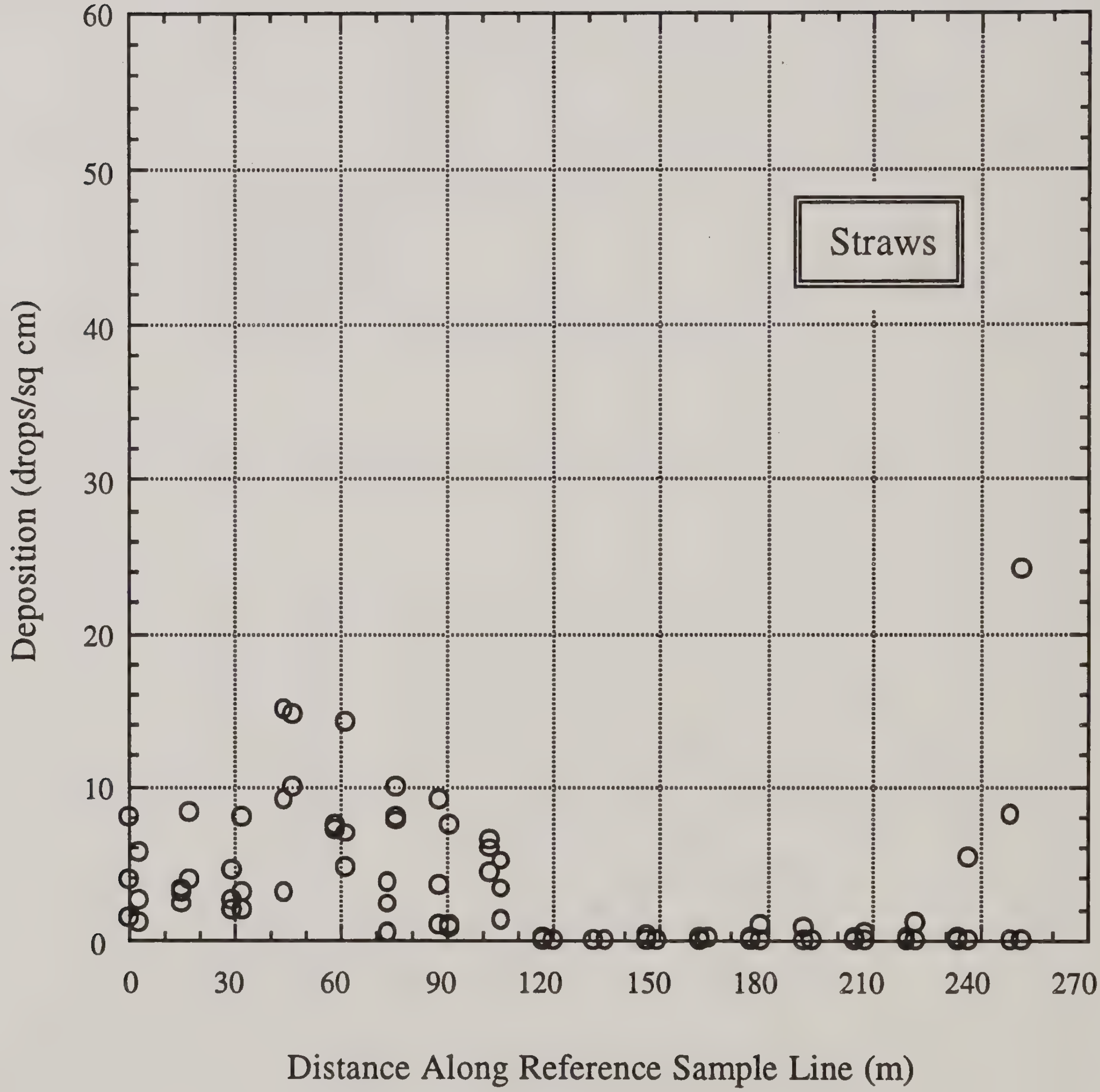


Figure 15: Charter orchard trial 2, field test deposition in drops per square centimeter for all **2.7-meter** elevation straws, shown along a reference sample line. Mean observed deposition for trial 2, 2.7 meter elevation straws = 6 drops/sq cm.

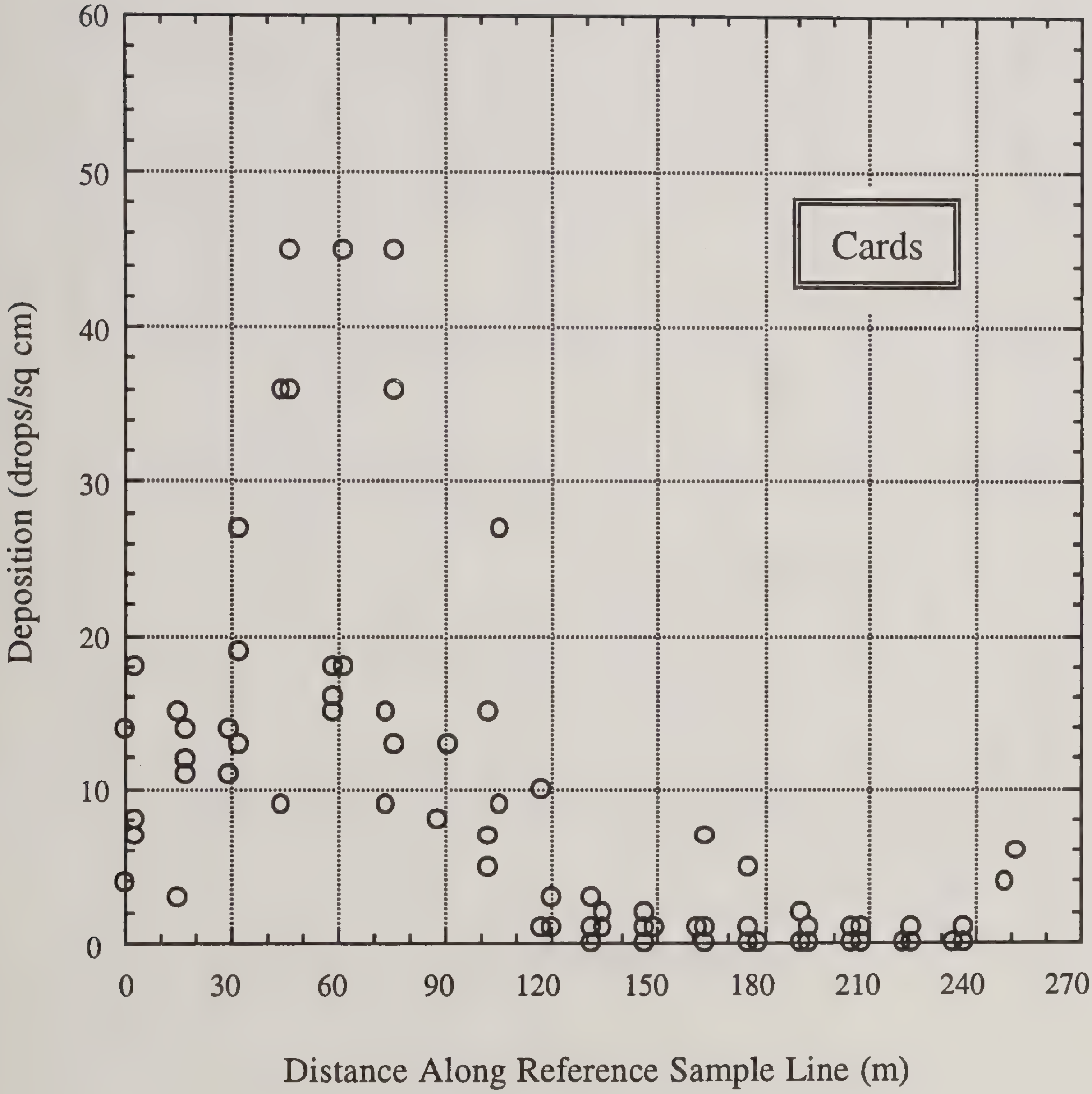


Figure 16: Charter orchard trial 1, field test deposition in drops per square centimeter for all **4.0-meter** elevation cards, shown along a reference sample line. Mean observed deposition for trial 1, 4.0 meter elevation cards = 17 drops/sq cm.

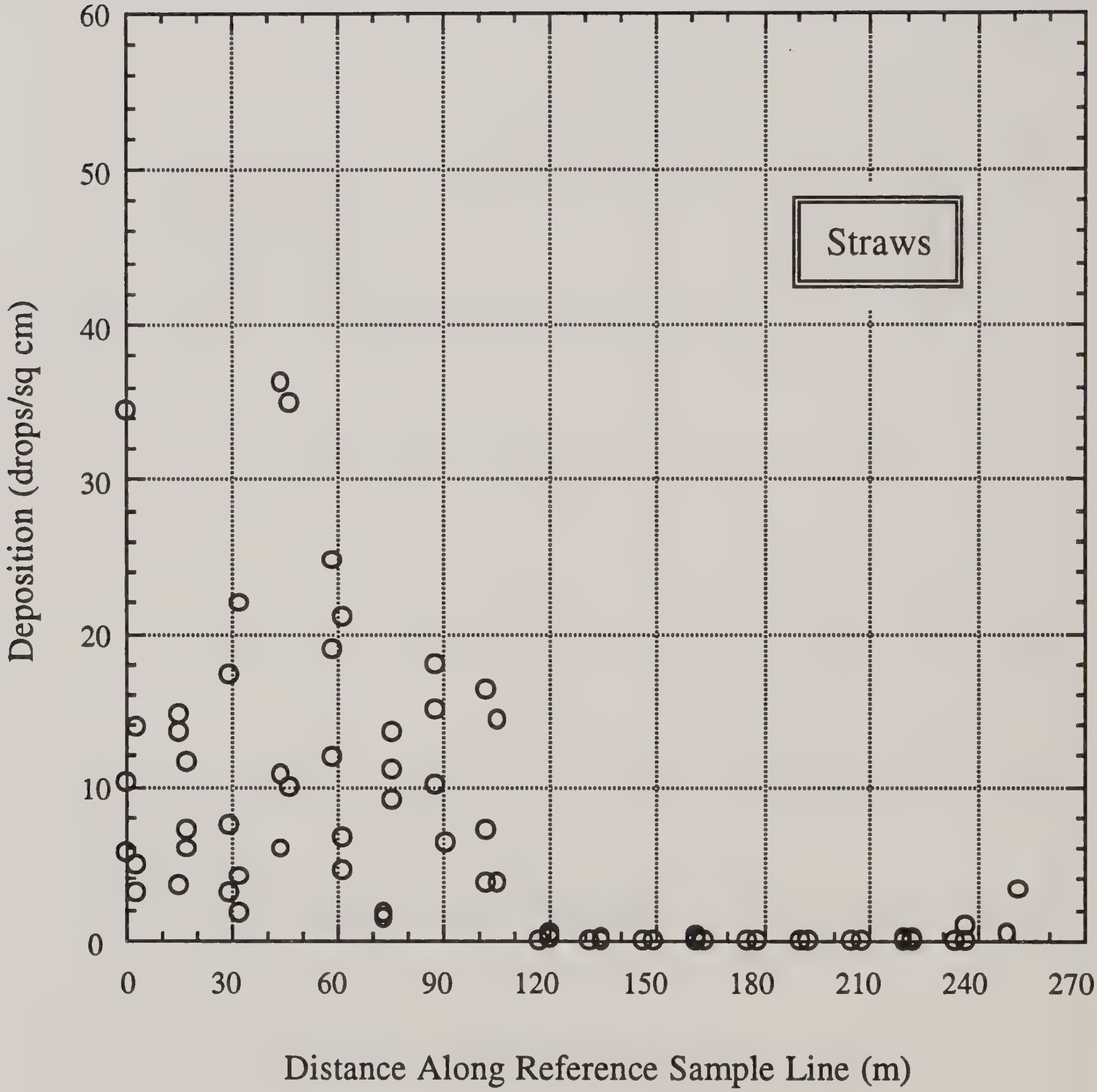


Figure 17: Charter orchard trial 1, field test deposition in drops per square centimeter for all **4.0-meter** elevation straws, shown along a reference sample line. Mean observed deposition for trial 1, 4.0 meter elevation straws = 12 drops/sq cm.

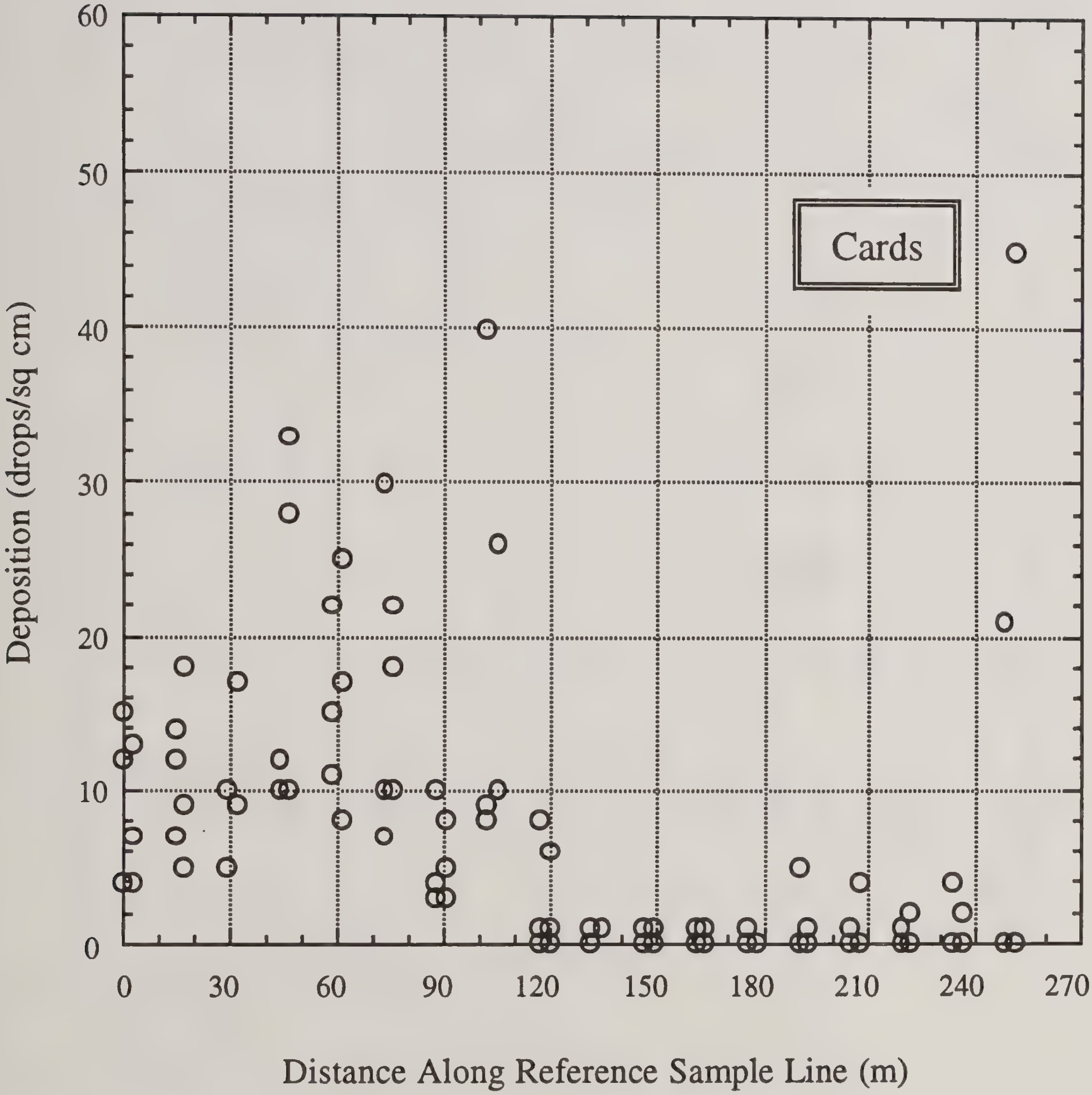


Figure 18: Charter orchard trial 2, field test deposition in drops per square centimeter for all **4.0-meter** elevation cards, shown along a reference sample line. Mean observed deposition for trial 2, 4.0 meter elevation cards = 13 drops/sq cm.

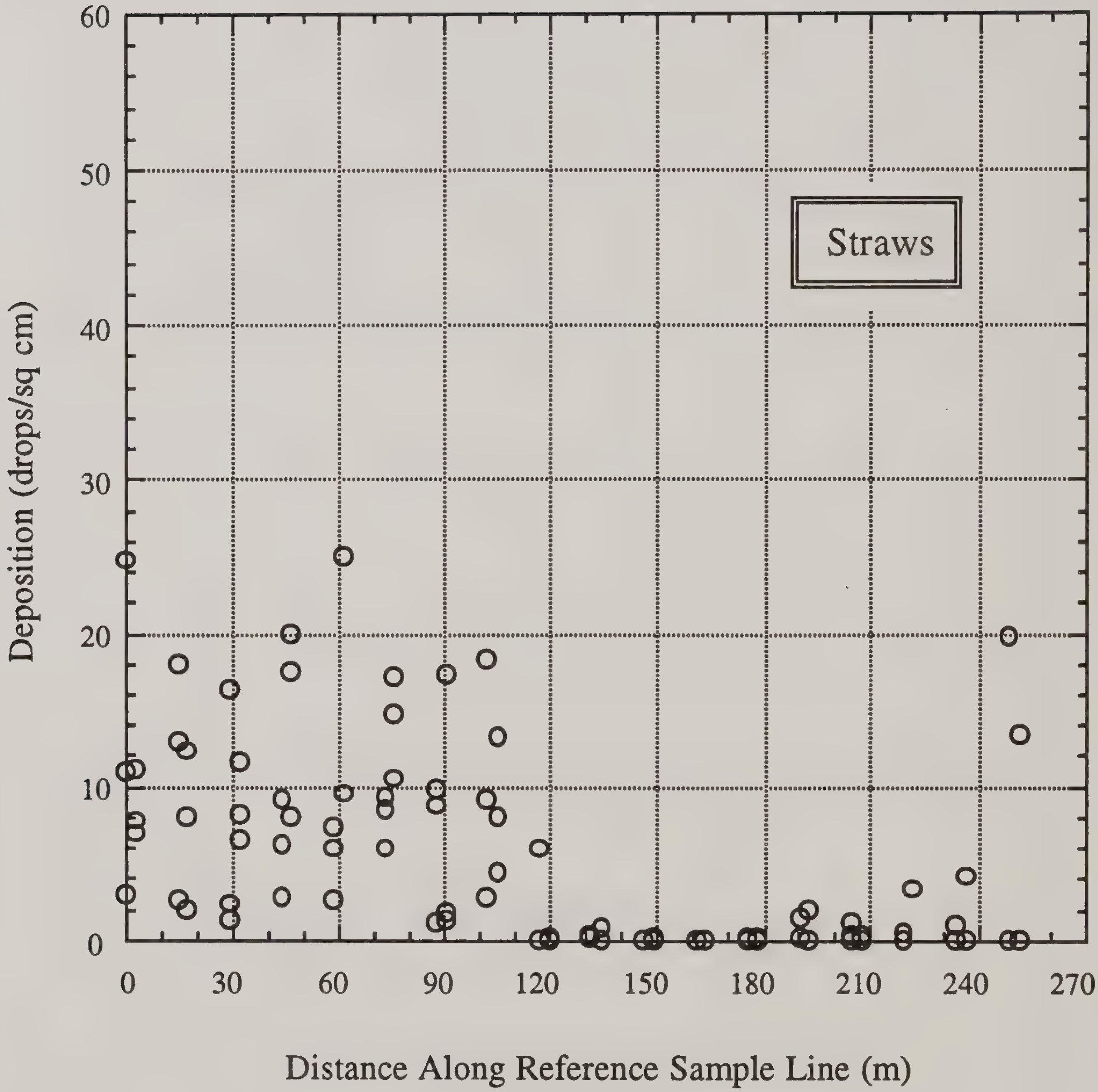


Figure 19: Charter orchard trial 2, field test deposition in drops per square centimeter for all **4.0-meter** elevation straws, shown along a reference sample line. Mean observed deposition for trial 2, 4.0 meter elevation straws = 10 drops/sq cm.

Table 5: Mean Field Test Drop Deposition In Treatment Blocks
(Straws and Cards)

MEAN DEPOSITION BY SAMPLE LINE (drops/cm^2)

		TRIAL 1				TRIAL 2			
		CARDS		STRAWS		CARDS		STRAWS	
ELEVATION	Sample Line	East	West	East	West	East	West	East	West
Ground	1	22	19	--	--	12	10	--	--
	2	15	14	--	--	8	9	--	--
	3	18	15	--	--	8	10	--	--
2.7 meters	1	13	10	14	9	13	9	5	6
(mid-canopy)	2	6	12	6	5	7	6	6	4
	3	14	11	10	13	11	11	6	5
4.0 meters	1	24	10	16	11	16	11	13	10
(upper canopy)	2	17	18	5	20	12	11	10	7
	3	24	10	10	8	15	16	10	8

MEAN DEPOSITION FOR ALL SAMPLE LINES (drops/cm^2)

	TRIAL 1				TRIAL 2			
	CARDS		STRAWS		CARDS		STRAWS	
ELEVATION	East	West	East	West	East	West	East	West
Ground	18	16	--	--	9	10	--	--
2.7 meters	11	11	10	9	10	9	6	5
4.0 meters	22	13	10	13	14	13	11	8

MEAN DEPOSITION BY COLLECTOR TYPE (drops/cm^2)

	CARDS		STRAWS	
ELEVATION	Trial 1	Trial 2	Trial 1	Trial 2
Ground	17	10	--	--
2.7 meters	11	10	10	6
4.0 meters	17	13	12	10

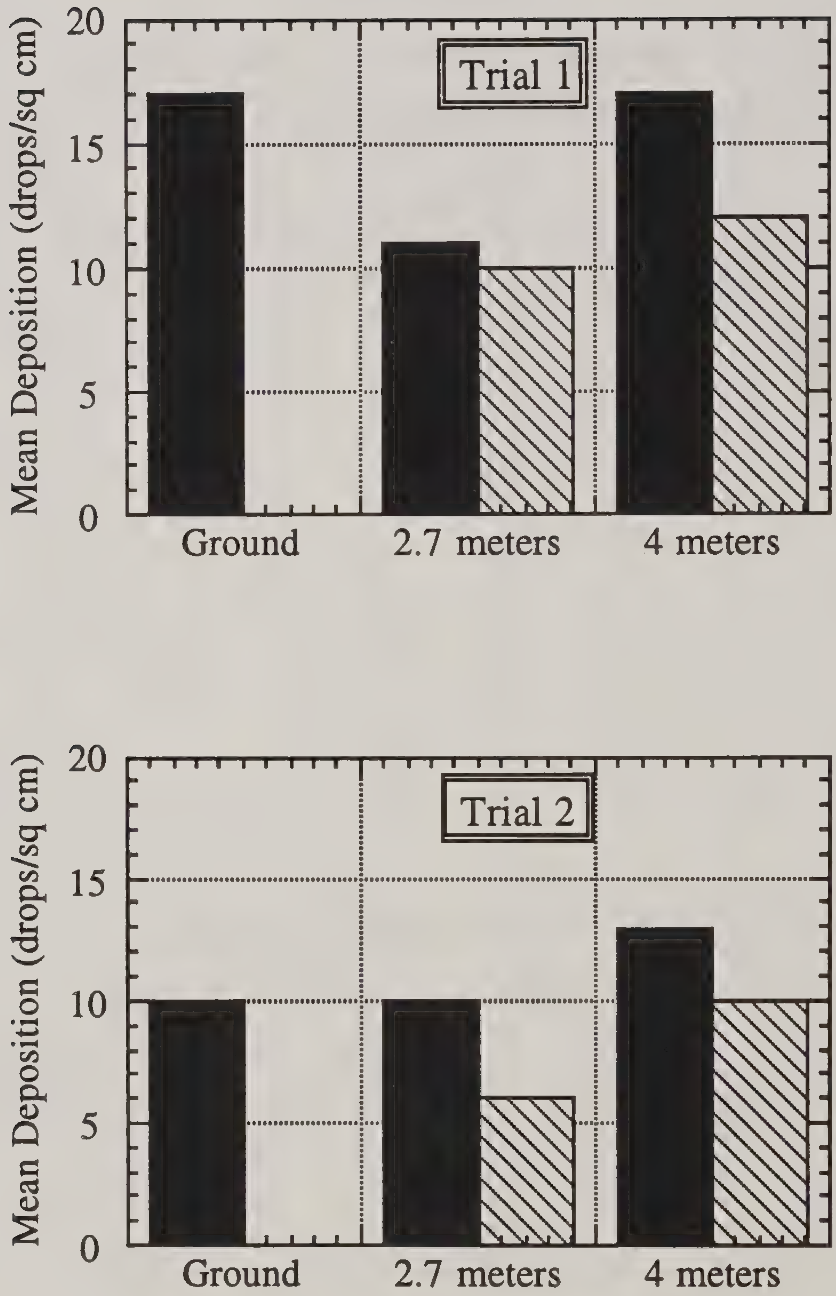


Figure 20: Mean deposition in drops per square centimeter observed in the canopy and on the ground, Charter orchard trials 1 (top) and 2 (bottom): data from card samplers are shown as solid bars, and from straw samplers as striped bars. Trial 1 was conducted during the popcorn stage of foliage, and trial 2 was conducted during the petal fall stage of foliage.

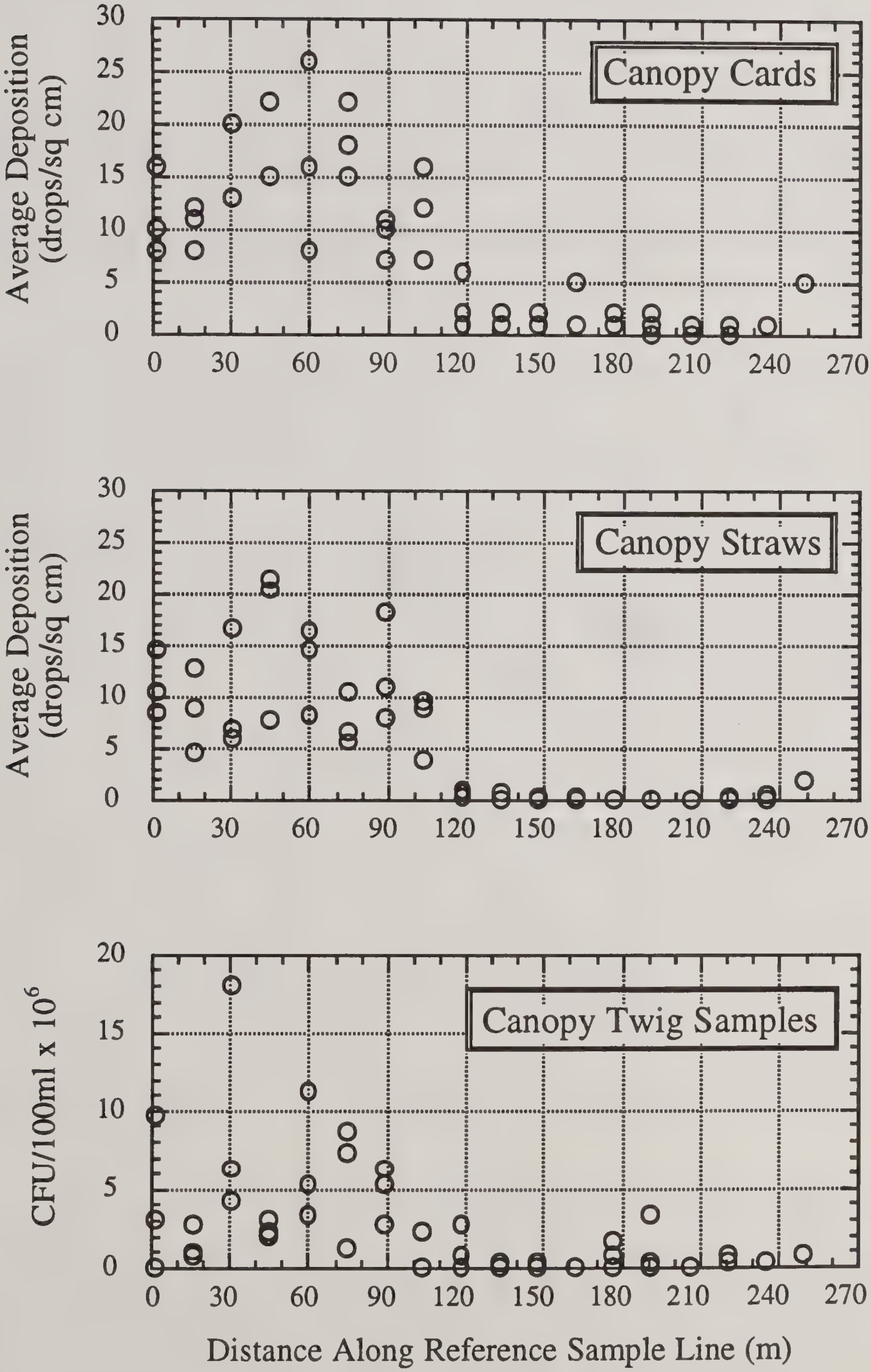


Figure 21: Trial 1 mean deposition in the canopy (averaged for all canopy sample positions in each tree and for all sample lines), by sample tree, for card samplers (top), soda straw samplers (middle), and twig samples from the upper canopy (bottom). Data are shown by sample tree position along a reference sample line.

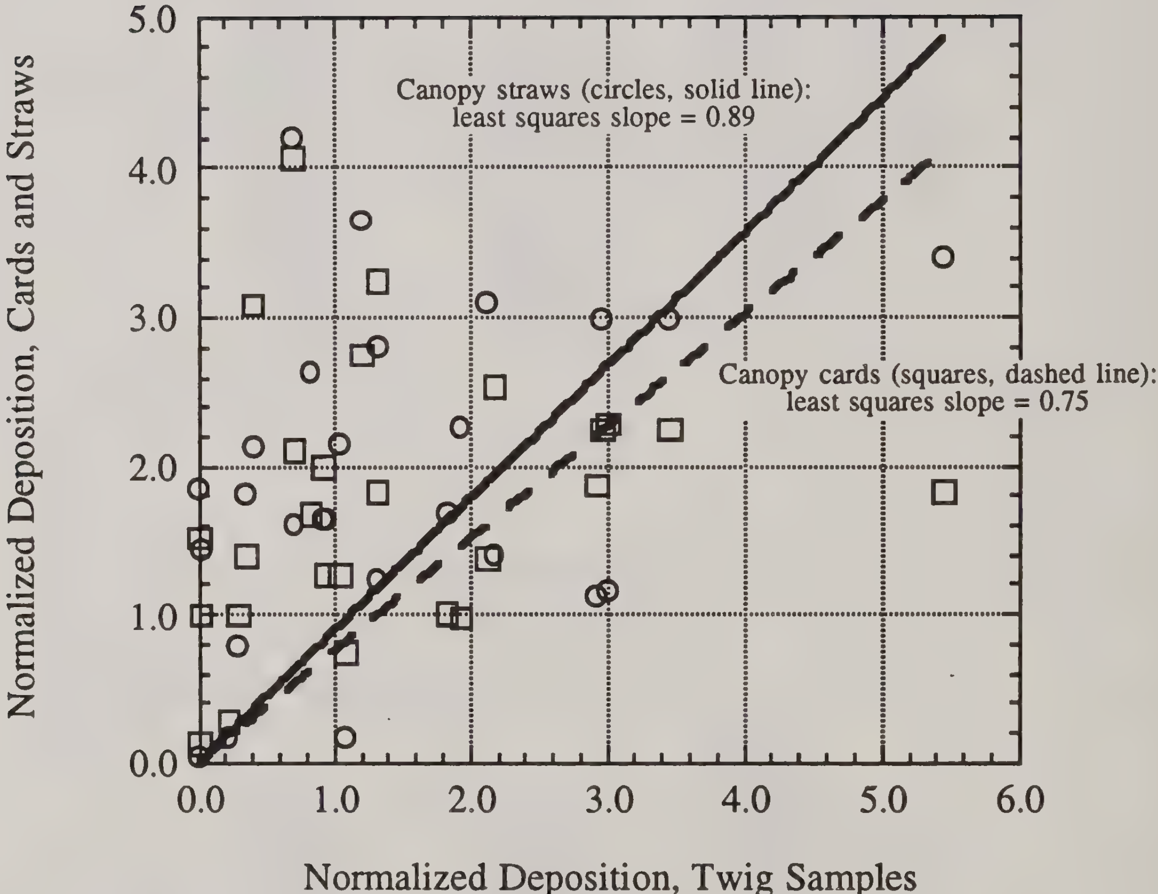


Figure 22: Trial 1, correlation of normalized mean deposition on canopy card samplers to normalized mean deposition on twig samples (open squares and dashed line) and correlation of normalized mean deposition on canopy straw samplers to normalized mean deposition on twig samples (open circles and solid line).

4. FSCBG Simulation of Deposition Data

Aircraft and spray system variables and canopy characteristics for the two trials conducted at Charter almond orchard in February and March, 1992, were used to simulate field test deposition data using the FSCBG aerial spray model, described in the introduction. The operation of FSCBG is further described in Teske and Curbishley (1991, 1994). Table 2 shows the orchard characteristics on each day of testing, and Table 3 shows the meteorological data recorded at the test site and at an IPM weather station nearby. Table 6 describes the aircraft and spray system used.

Since a uniform canopy is assumed, and since trials were conducted over similar periods of time during the day, general meteorological conditions inside the canopy can be assumed to be uniform from sampler position to sampler position at each elevation, even though meteorological data recorded at the test site were measured about 15 meters (50 feet) from canopy edge at an elevation of 1.5 meters (5 feet). Teske et al. (1993a), who used these same Charter orchard trials to study FSCBG application to canopy penetration and deposition, noted that wind speed measured above or outside a canopy may not be useful when deciding on the wind speed to use within a canopy, and that wind direction may change by over 100 degrees from outside a canopy to within it. In order to reflect the nearly quiescent horizontal wind motion present within the canopy during spraying, they decided to use a nominal layer mean wind speed for their study of this dataset. However, because meteorological data were recorded in the orchard at the time of spraying, FSCBG simulations presented in this study use the on-site data as the basis for open terrain meteorological inputs and assume a reduction of wind speed by half within the canopy (not exceeding 1.0 m/s). The on-site meteorological data are shown as "field data" in Table 3. When these data are not available, an average of the two IPM readings is used. Table 3 shows that meteorological conditions at Charter orchard on February 25 were relatively quiescent, whereas on March 3 there was a crosswind of nearly 3 m/s recorded.

Drop distribution data for the Micronair rotary atomizers used in both trials are given in Table 7. The distribution shown is an approximation of the actual spray system used in the trials, and was included in the Charter orchard study plan (J.W. Barry, private communication, 1992). Although the FSCBG drop size distribution library includes other drop distribution data for Micronair AU5000 rotary atomizers spraying similar Bt formulations, this distribution was chosen to most closely match the volume median diameter (VMD) that the test conditions were believed to produce (J.W. Barry, private communication, 1992).

Data from the aircraft characterization trials (described in section 2.5) include volumetric data in ounces per acre as well as drop deposition data in drops per square centimeter. The aircraft characterization trials were simulated with FSCBG using the drop distribution data shown in Table 7, the aircraft and spray system characteristics listed in Table 6, and the meteorological data available. Drop and volume data from the four passes of the aircraft were averaged for each of the 20 cards placed on the sample line to give average observed drop and volume deposition for the characterization trials. These are compared to FSCBG predictions for drop and volume deposition in Figures 23 and 24. FSCBG predicts the volume deposition very well, and overpredicts drop deposition slightly. The average observed VMD for the characterization trials is 145 micrometers; the average

observed NMD is 155 micrometers. FSCBG predicts average VMD = 135 micrometers and average NMD = 100 micrometers. The characterization trials were conducted over flat terrain with no canopy.

The Charter orchard trials were conducted when the almond tree canopy was at two different stages of flower and foliage, as shown in Table 2: the bloom swelling, or popcorn, stage (February 25); and the petal fall stage (March 3). The presence of a canopy removes spray material by presenting more vegetative elements for impaction. The probability that a drop will penetrate a canopy depends on the total number and size of vegetative elements encountered, droplet specific gravity, drop size, fall velocity, aircraft wake turbulence, and micrometeorology. Since the orientation of the vegetative elements is assumed to be random, the probability of penetration for a given path length will be the same for all directions. Teske et al. (1993a) describes the canopy penetration model used in FSCBG in detail. The probability of penetration is either assigned according to tree type based on foliage density and envelope dimensions, or is determined from optical measurements as a function of sun incidence angle. For the Charter orchard almond trees, this parameter was evaluated in the study of FSCBG application to canopy spray penetration, by Teske et al. (1993a) and assisted by Pat Skyler and John Barry, USDA Forest Service. Penetration probabilities of 0.2 in the popcorn stage and 0.4 in the blossom petal fall stage were found to be representative of the orchard at the time of the trials. The same values are used in this report.

The position of the spray aircraft during each trial is known; the aircraft flew 14.6-meter swaths, as shown in Figure 1, that were perpendicular to the lines of samplers. As mentioned in the previous section, the three lines of samplers were actually replicates of each other; and, although the characteristics of the canopy over each line may have been slightly different, FSCBG assumes a uniform canopy. Thus, to simulate the amount of spray descending into the canopy (and through to the ground), the spray aircraft was modeled to fly swaths as indicated in Figure 1 over one reference sample line, with sampler positions as shown in Figure 9, extending across one treatment block and an untreated control block. Discrete receptors for deposition were placed at three elevations (ground level, 2.7 meters and 4.0 meters) at each of the sampler positions along the line of trees. FSCBG simulations were done for discrete receptors that were horizontally positioned cards and for discrete receptors that were horizontally positioned cylinders modeled after the polyethylene soda straw collectors described in the previous section.

Because of the scatter in the field data, deposition data from trial 1 were used for a sensitivity study of several modeling parameters known to have varied during the Charter orchard trials: of particular interest were the meteorological variables wind speed and wind direction. Figure 25 shows the deposition on ground cards and 4.0-meter cards at three wind directions: 300 degrees, 320 degrees, and 350 degrees. Figure 26 shows the deposition on ground cards and 4.0-meter cards at three wind speeds: 1.0 m/s, 1.3 m/s and 1.6 m/s. It is apparent from the figures that both of these meteorological variables have a large impact on FSCBG predictions, changing not only the levels of deposition predicted in the canopy and on the ground, but also the shape of deposition over the line of sample trees. Teske and Barry (1993) examined the sensitivity of input variables entered into FSCBG, determining a sensitivity factor for all controllable input variables. The sensitivity factors they generated not only suggest accuracy of FSCBG predictions, but also may be used to infer the accuracy needed to maintain conditions during an actual spray mission. Of those modeling parameters that cannot be rigorously controlled during a spray mission, three of

the most important in terms of their effect on deposition profile over the target area are release height, wind direction and wind speed.

The results presented here use a wind speed of 1.3 m/s and a direction of 320 degrees for trial 1, and a wind speed of 2.7 m/s and a direction of 170 degrees (the actual measured values) for trial 2. These values are considered the best compromise that can be made with the available knowledge about the field meteorology.

Release height over the canopy was variable and fairly low: 3 to 4.5 meters above the canopy for trial 1, and 4.5 to 6 meters above the canopy for trial 2; mean canopy height was 6.1 meters. As mentioned above, predictions of deposition have been found to be very sensitive to release height: according to Teske and Barry (1993), if the release height is only known to within 30-50% (as is the case for the Charter trials), the deposition pattern will be predicted by FSCBG can differ by as much as 85% from the pattern that FSCBG would predict if the exact release height were entered. Since FSCBG requires a constant release height, the averages of 3.75 meters above the canopy for trial 1 and 5.25 meters above the canopy for trial 2 were considered the best compromise that could be made.

The deposition levels predicted for trials 1 and 2 are compared to field data in Figures 27 through 36. As is apparent from these figures, FSCBG predictions using the inputs discussed above correlate well with the levels of deposition seen in the field data, as well as with the deposition profiles over the lines of sample trees. Field data bracket the deposition predicted on both card and straw discrete receptors, for all elevations and for both trials. While the shape of the deposition profiles predicted for trial 2 is consistently close to that observed in the field, the shape of the observed deposition profiles for trial 1 suggests that the wind direction may have been close to 360 degrees (a headwind for the swaths flown from south to north). In both trials, there was significant deposition observed at the end of the sample line placed in treatment block 1 (line 1 in Figure 1); these data points are at approximately 240-250 meters along the single sample line shown in Figures 27 through 36. Sample tree 18 on this line was almost on the edge of treatment block 2, and would have been subject to drift from the swaths flown over that treatment block, all the more so if the wind direction were 360 degrees (or coming slightly from the northeast, for example from 5-10 degrees). Downwind drift will be discussed in detail in the next section.

For a quantitative evaluation of the correlation between predicted and observed deposition, Table 8 shows the mean predicted deposition at each elevation in the canopy, for trees in the treatment blocks only, compared to the mean observed deposition at these elevations (shown previously in Table 5). Although mean FSCBG predictions are generally very close to the mean data observed in the trials, deposition at 2.7 meters is overpredicted for both types of collector, particularly for trial 1. This suggests that either the probability of penetration or the tree envelope are not exactly representative of the canopy encountered by the spray. Nevertheless, FSCBG predictions show good correlation to the field data for both types of collectors modeled. Figure 37 compares the mean deposition levels from Table 8 for both Charter trials. Correlation of mean predicted and observed deposition shows least squares slopes of 1.18 for trial 1 and 1.10 for trial 2; $R^2 = 0.44$ for trial 1 and $R^2 = 0.90$ for trial 2. The poorer correlation for trial 1 is due to poorer correlation at the lower canopy elevation (2.7 meters) for both cards and straws. The variation in release height recorded in the field is typical of this type of operational field trial (J.W. Barry, private communication, 1996), but is significant enough to change anticipated results substantially. FSCBG cannot

account for the effect of changing release height during the trial. Since these changes are typical, the correlation of predicted and observed deposition in trial 1 ($R^2 = 0.44$) is within the acceptable range for an operational field trial.

To compare FSCBG predicted deposition to the deposition observed on twig samples, it would be necessary to know the amount of Bt spore in a quantity of the formulation sprayed. These data are not available for the Charter trials.

Table 6: Aircraft Characteristics for Charter Trials 1 and 2

Aircraft Type	Schweizer Ag Cat Super B
Weight (kg)	2421
Wing Span (m)	12.9
Vertical Distance Between Wings (m)	1.9
Planform Area (sq m)	36.8
Drag Coefficient	0.10
Propeller Radius (m)	1.34
Propeller Efficiency	0.80
Blade RPM	2300
Number of Nozzles/Atomizers	6
Nozzle Type Assumed	Micronair
Flow Rate (gal/min)	0.5
Spraying Speed (m/sec)	49.2

Table 7: Drop Size Distribution Assumed for Trials 1 and 2

Drop Diameter (micrometers)	Mass Fraction
56.00	.1013
89.00	.1956
122.00	.3482
154.00	.2393
187.00	.0875
219.00	.0238
252.00	.0035
284.00	.0004
318.00	.0002
351.00	.0001
382.00	0
414.00	0
447.00	.0001

	1.0000

The distribution above is for Micronair AU5000 atomizers at 8400 rpm and blade angle of 35 degrees, spraying undiluted NOVO Foray 48B, 100 mph. This drop size distribution was included in the study plan for the Charter trials (J.W. Barry, private communication, 1992). The volume median diameter (VMD) of the spray is given as $D_{V.5}$ = 109.3 micrometers.

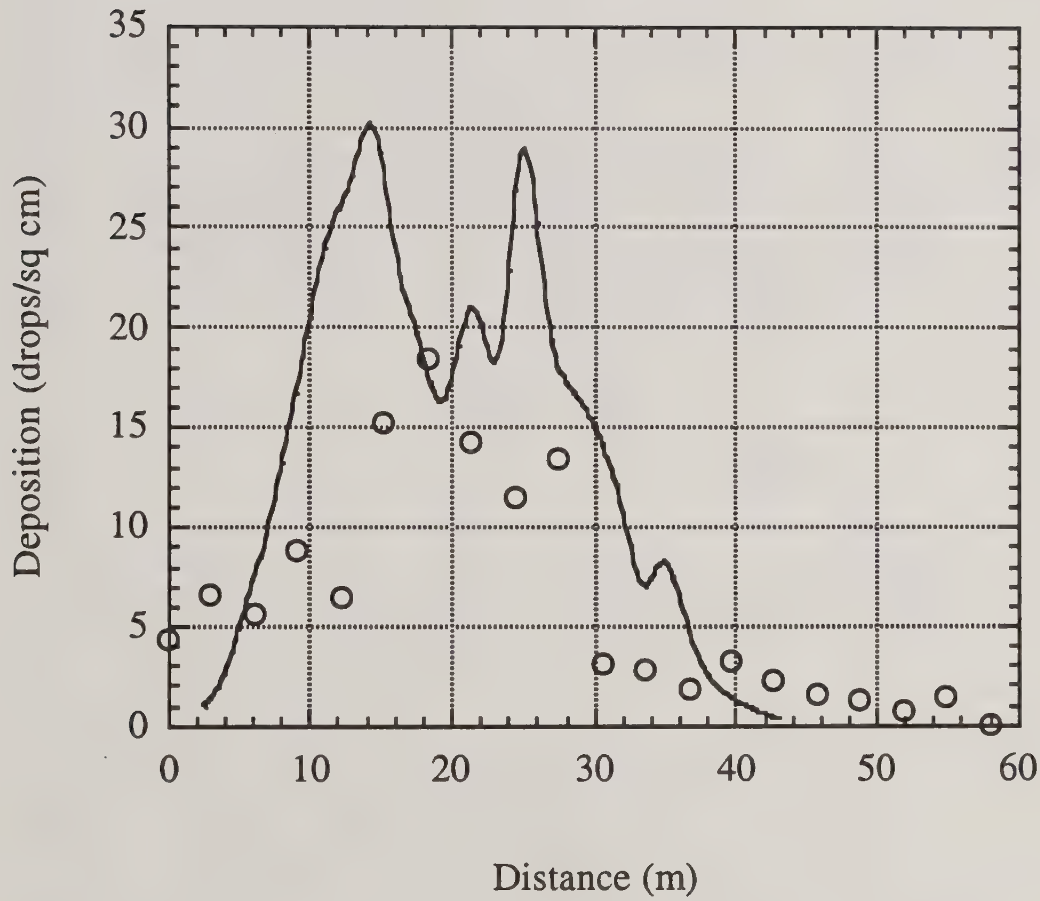


Figure 23: Aircraft characterization trials, drop deposition data in drops per square centimeter, averaged for four passes over the sample line and compared to FSCBG predicted drop deposition. Field test data are shown as open circles, predicted deposition is shown as a solid line.

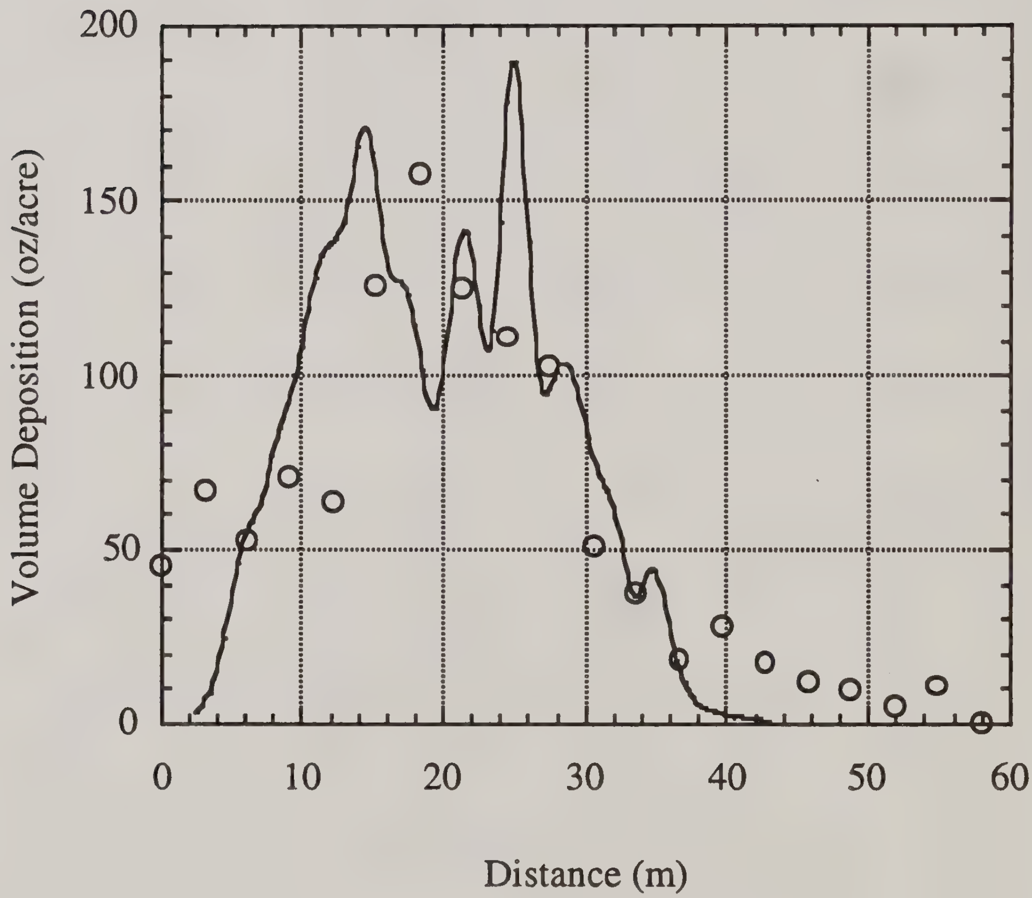


Figure 24: Aircraft characterization trials, volume deposition data in ounces per acre, averaged for four passes over the sample line and compared to FSCBG predicted volume deposition. Field test data are shown as open circles, predicted deposition is shown as a solid line.

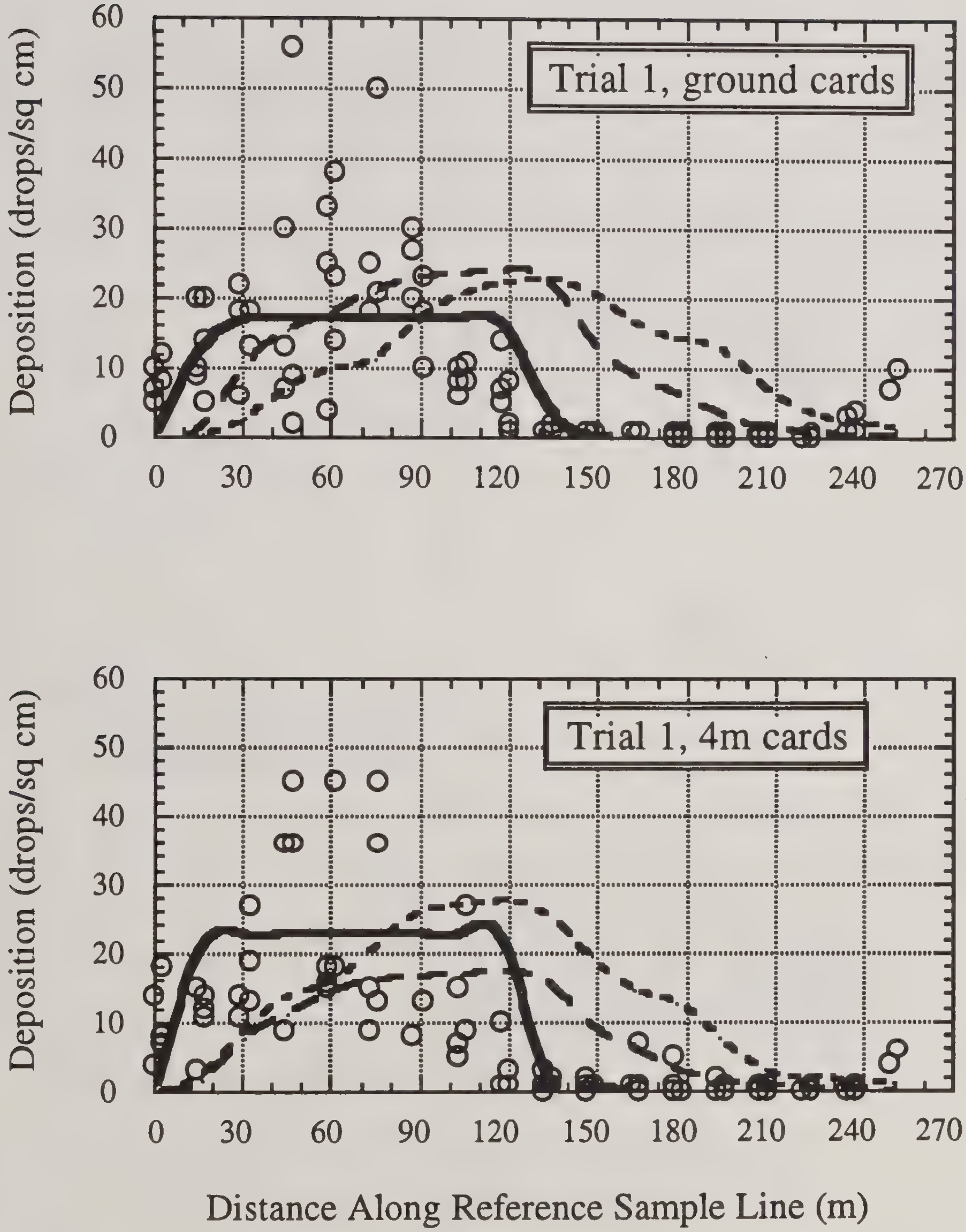


Figure 25: Sensitivity of predicted deposition to wind direction outside the canopy: predicted deposition on the ground (top) and at 4.0 meters (bottom) for trial 1, at three wind directions, in drops per square centimeter. Field test data for trial 1 are shown as open circles. FSCBG predictions are shown as lines: wind direction 350 degrees, solid line; wind direction 320 degrees, large dashed line; wind direction 300 degrees, small dashed line.

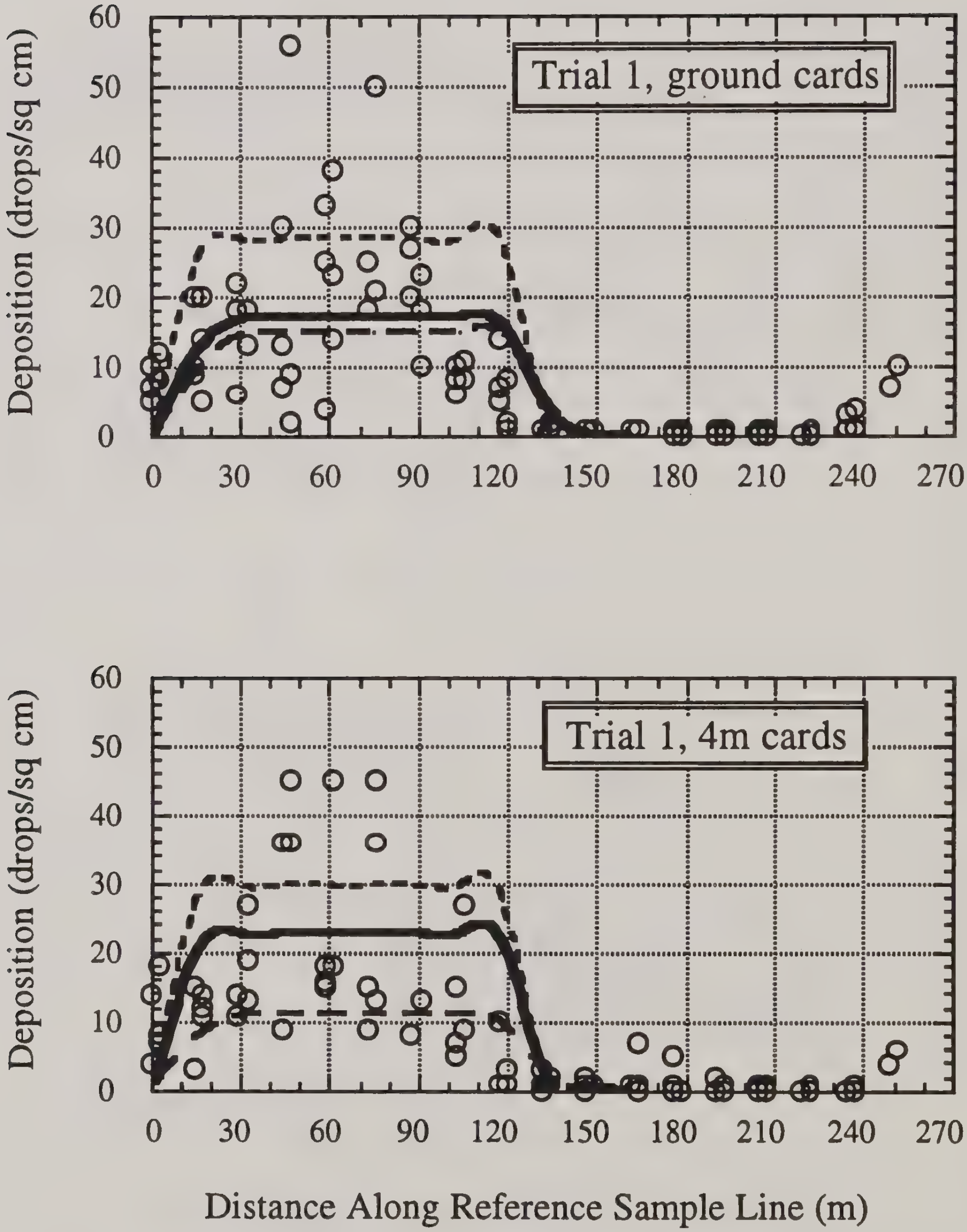


Figure 26: Sensitivity of predicted deposition to wind speed outside the canopy: predicted deposition on the ground (top) and at 4.0 meters (bottom) for trial 1, at three wind speeds, in drops per square centimeter. Field test data for trial 1 are shown as open circles. FSCBG predictions are shown as lines: wind speed 1.3 m/s, solid line; wind speed 1.6 m/s, large dashed line; wind speed 1.0 m/s, small dashed line.

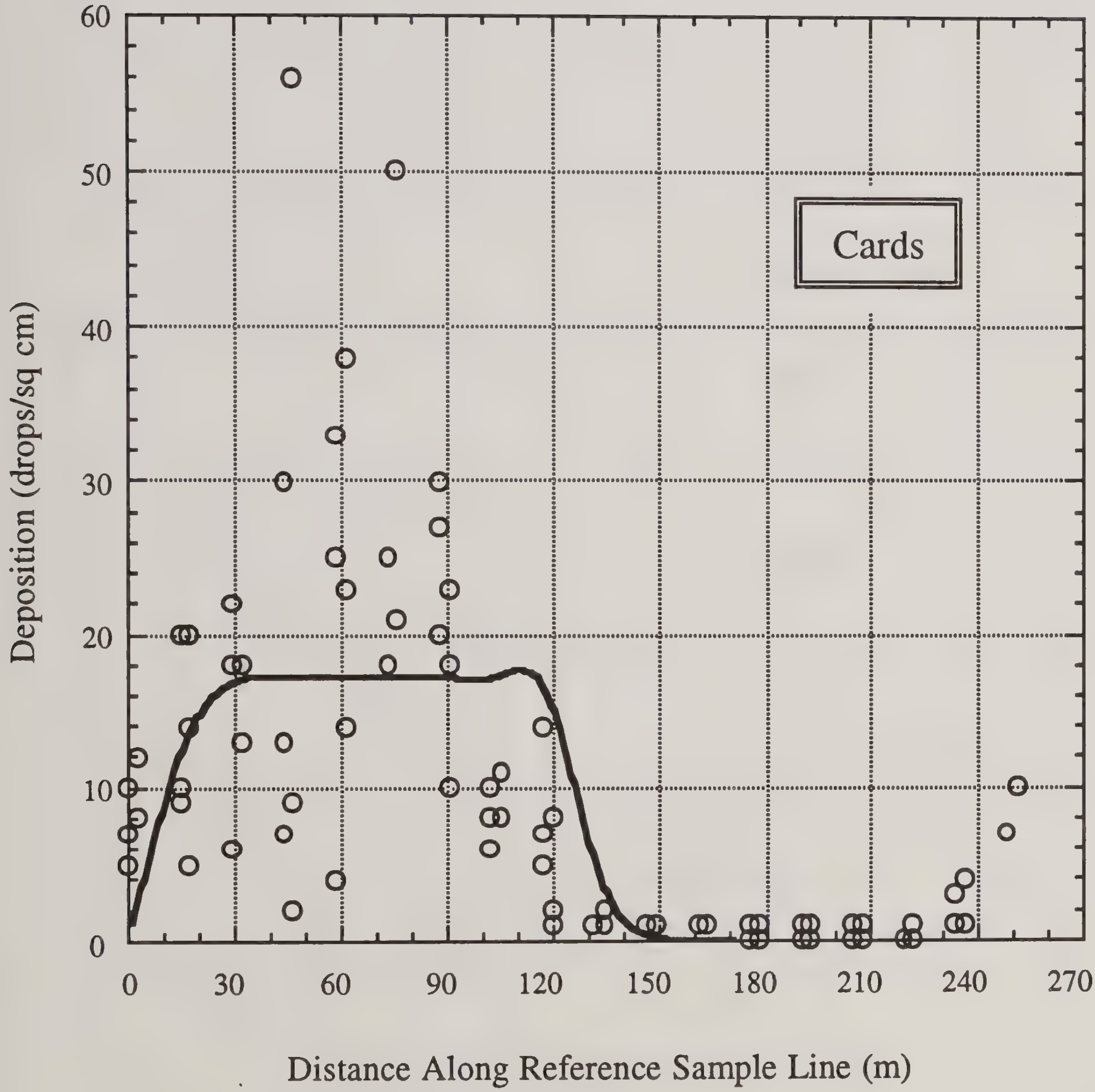


Figure 27: Trial 1: FSCBG predicted deposition over a reference sample line, card samplers at **ground** level, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

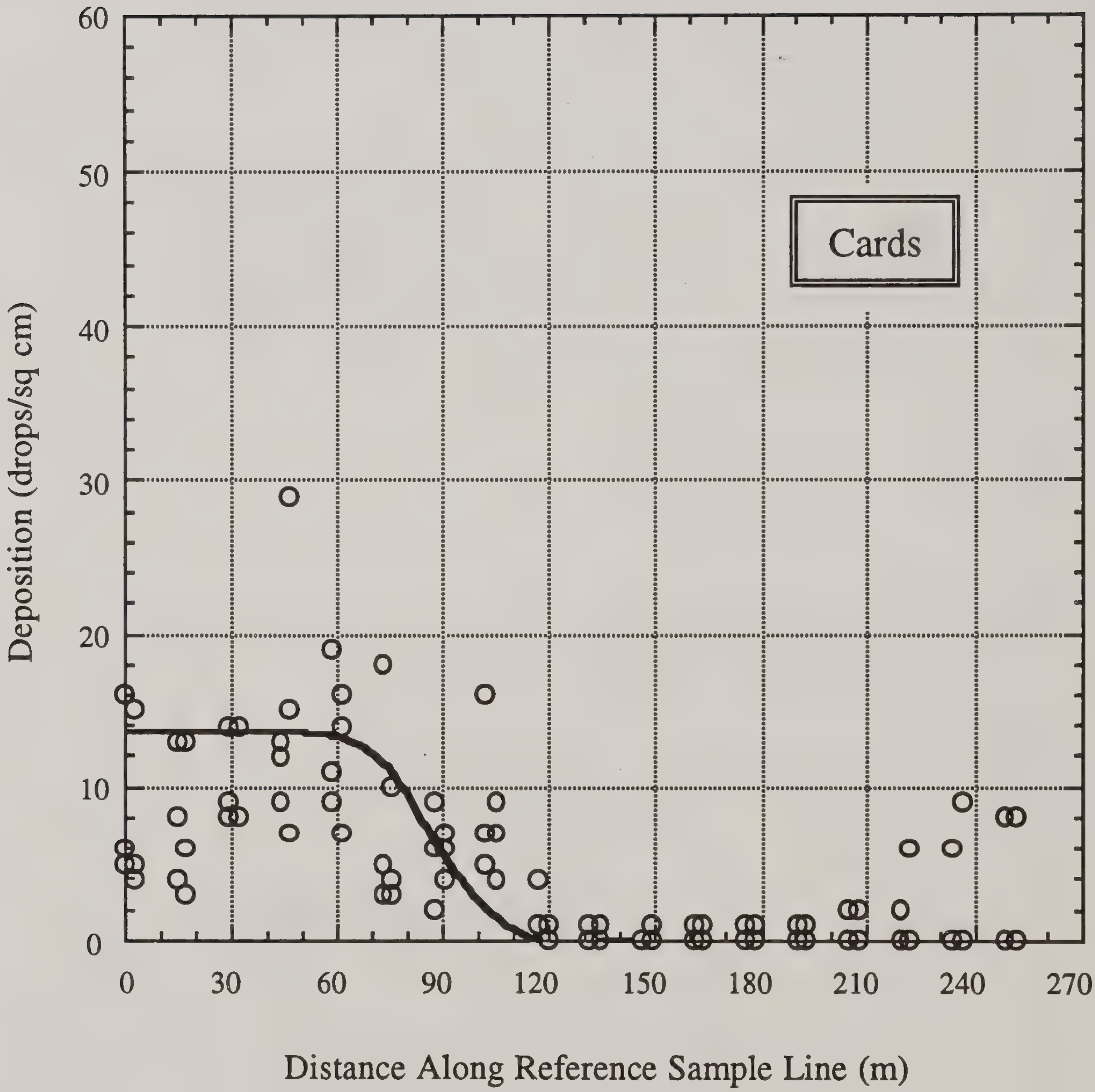


Figure 28: Trial 2: FSCBG predicted deposition over a reference sample line, card samplers at **ground** level, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

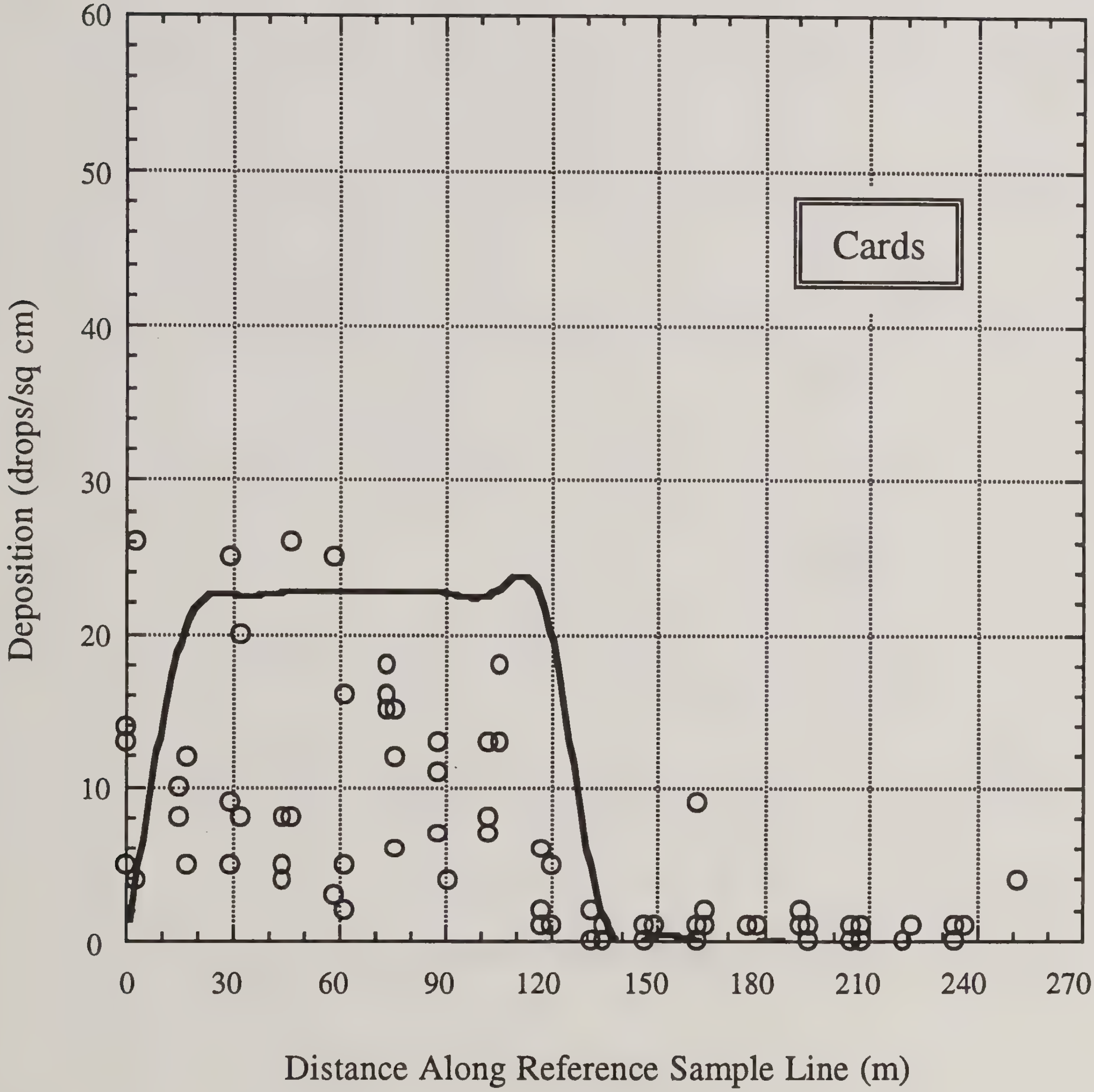


Figure 29: Trial 1: FSCBG predicted deposition over a reference sample line, card samplers at **2.7-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

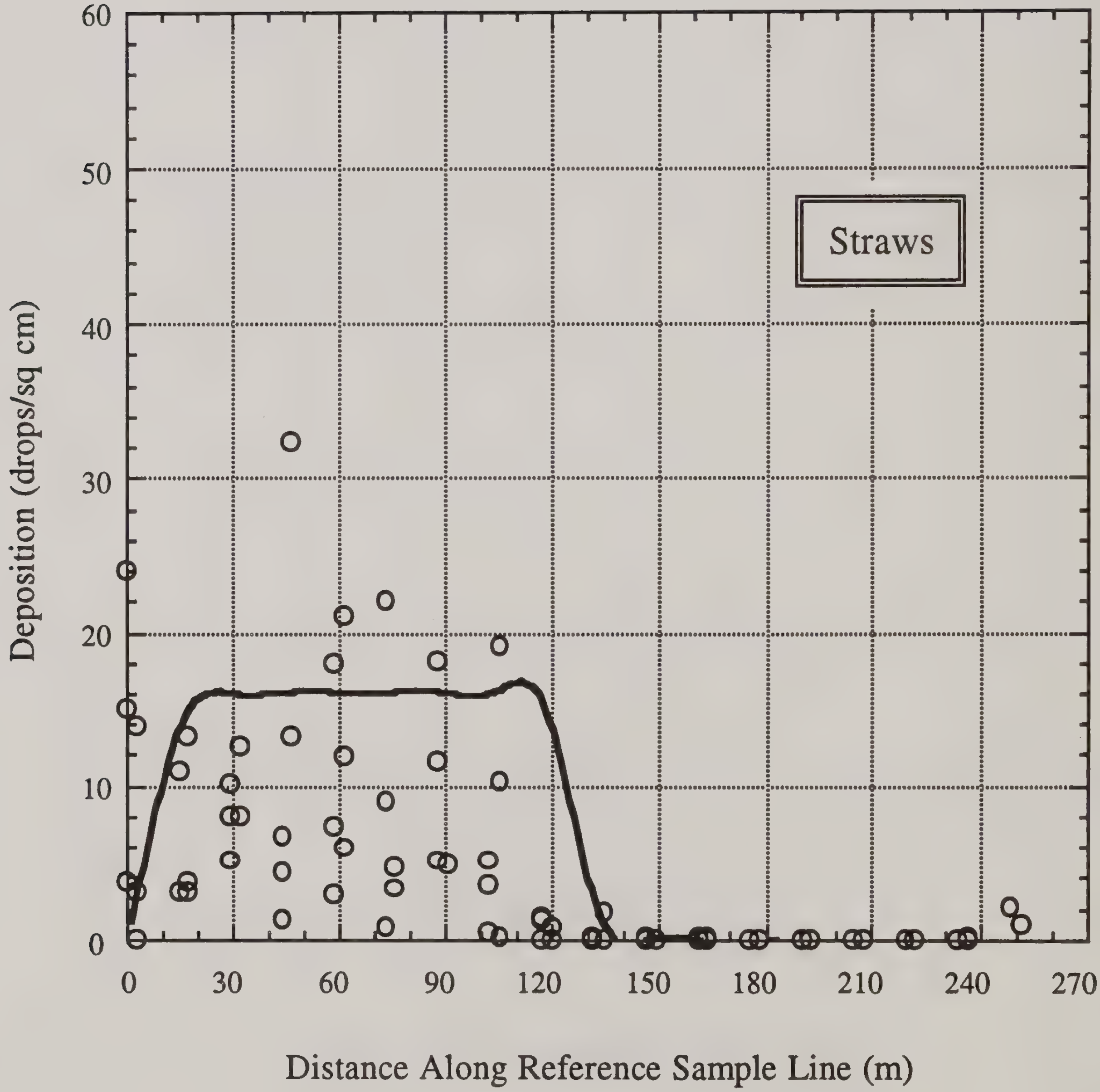


Figure 30: Trial 1: FSCBG predicted deposition over a reference sample line, straw samplers at **2.7-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

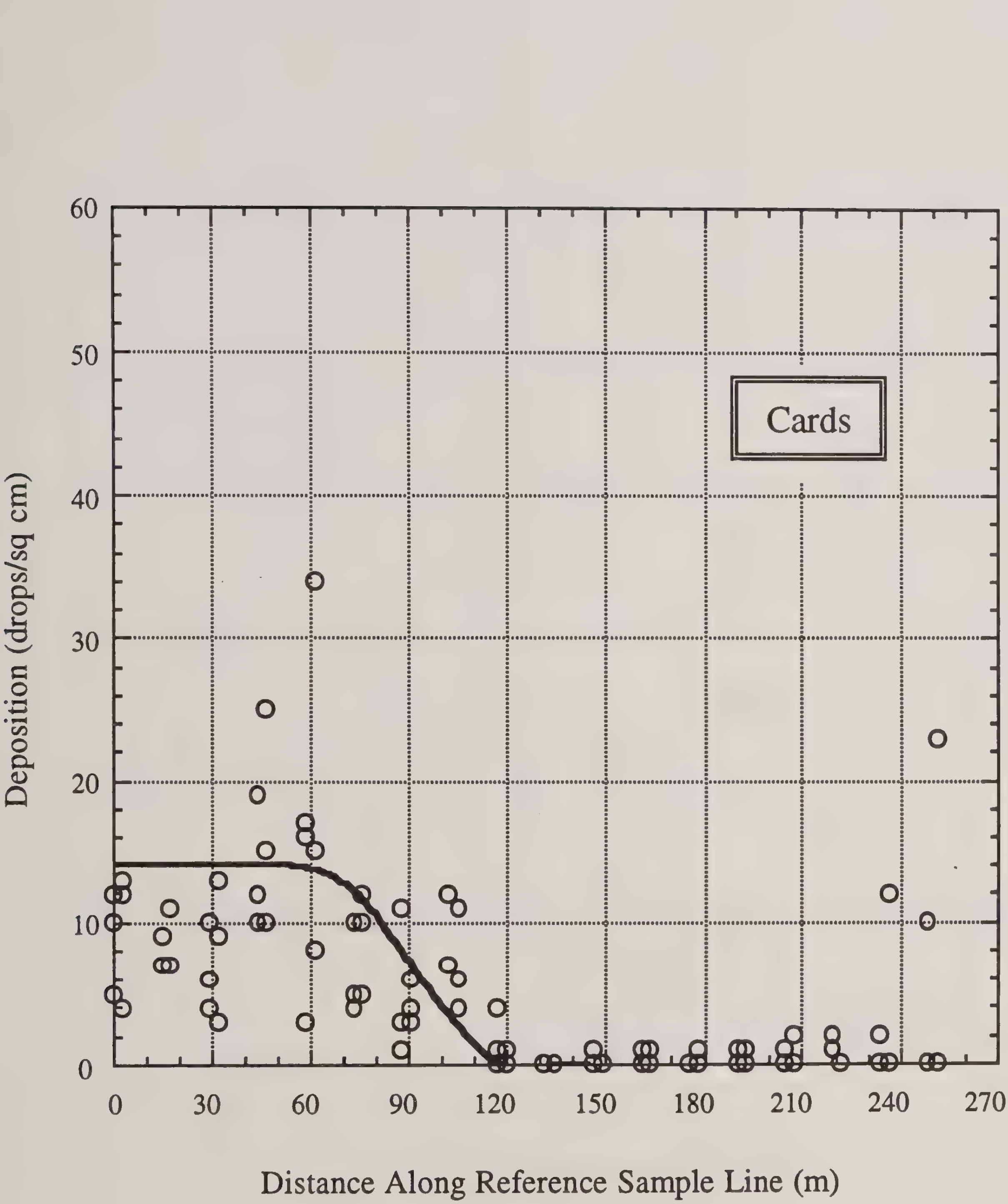


Figure 31: Trial 2: FSCBG predicted deposition over a reference sample line, card samplers at **2.7-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

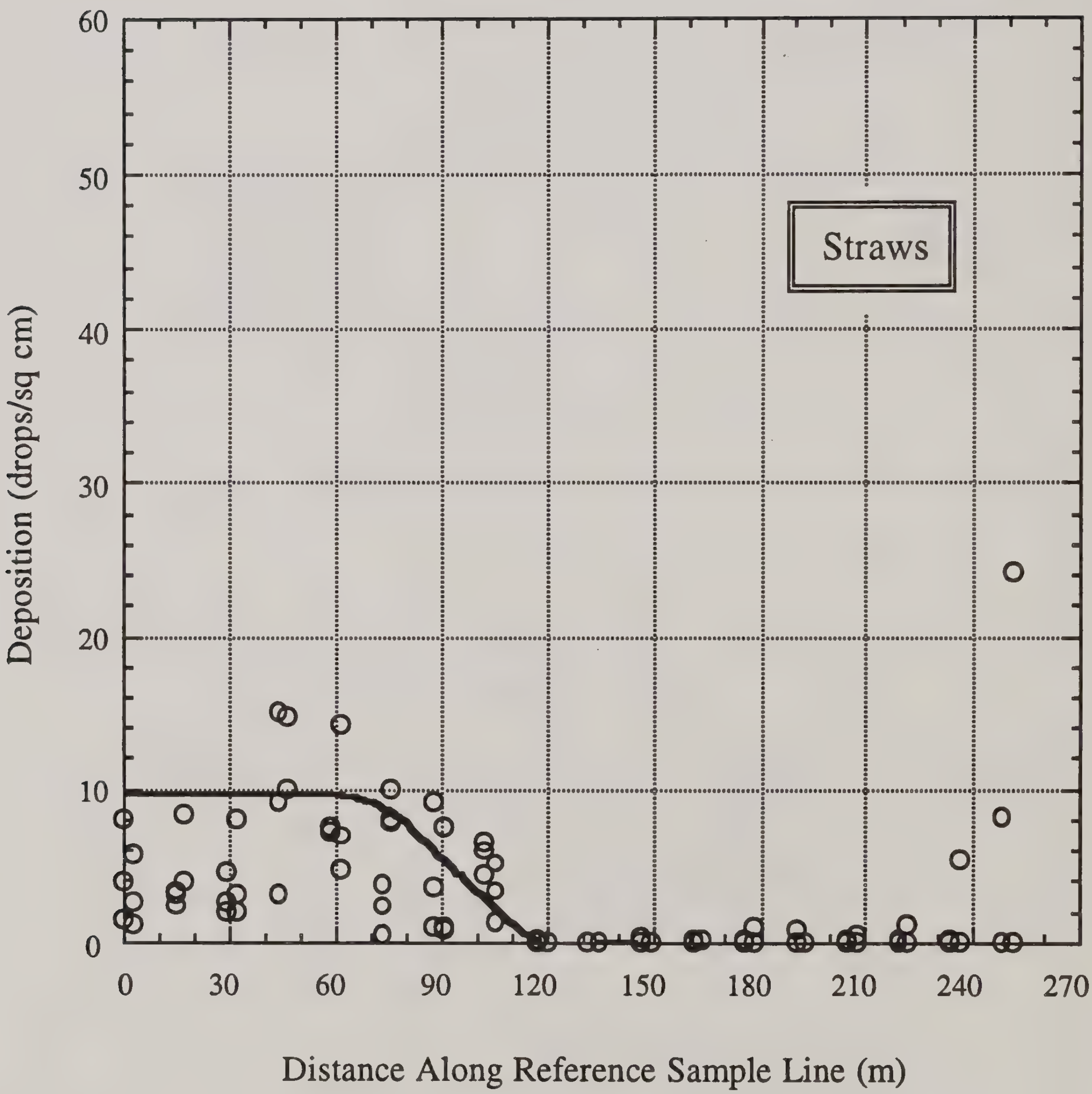


Figure 32: Trial 2: FSCBG predicted deposition over a reference sample line, straw samplers at **2.7-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

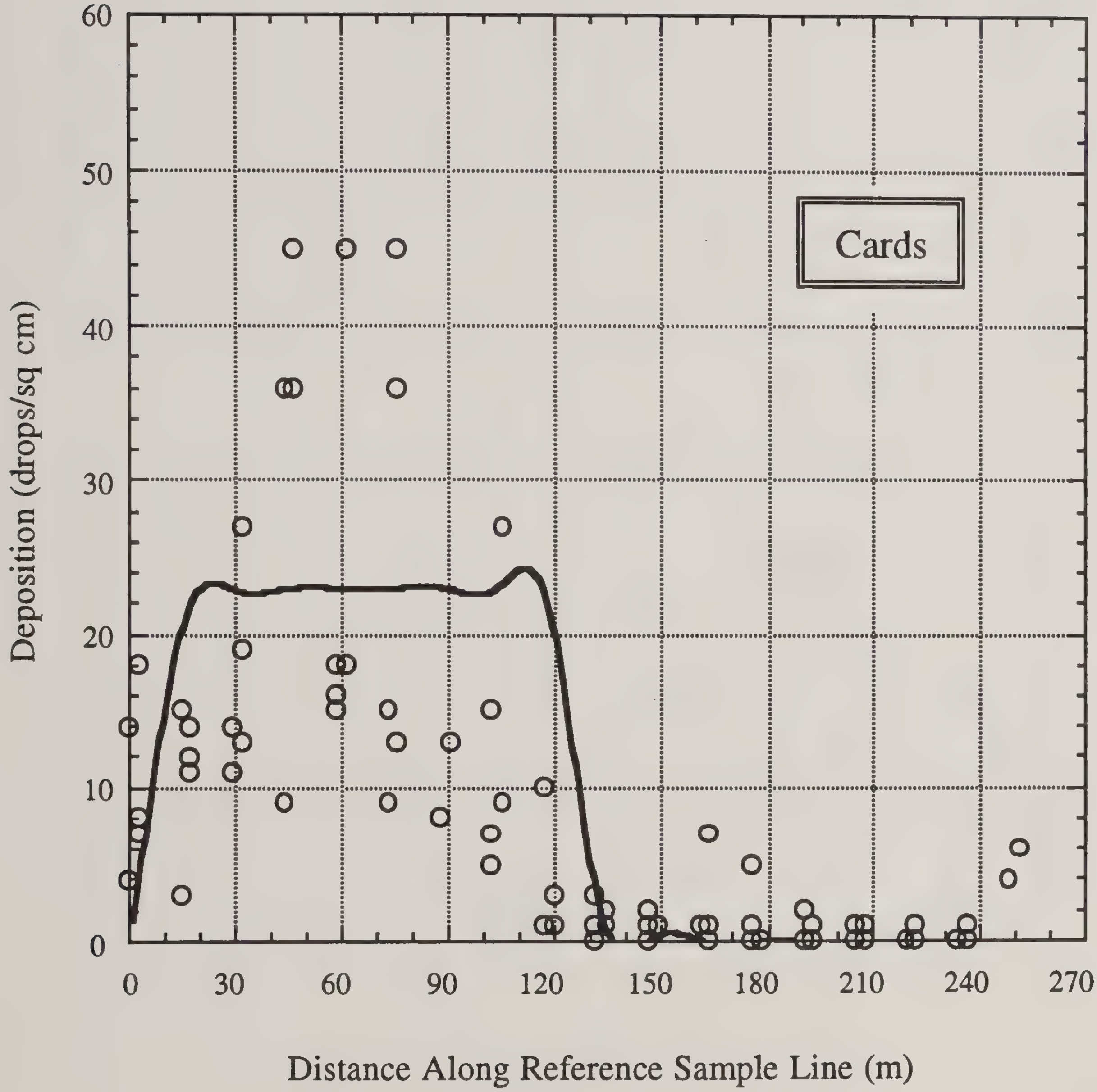


Figure 33: Trial 1: FSCBG predicted deposition over a reference sample line, card samplers at **4.0-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

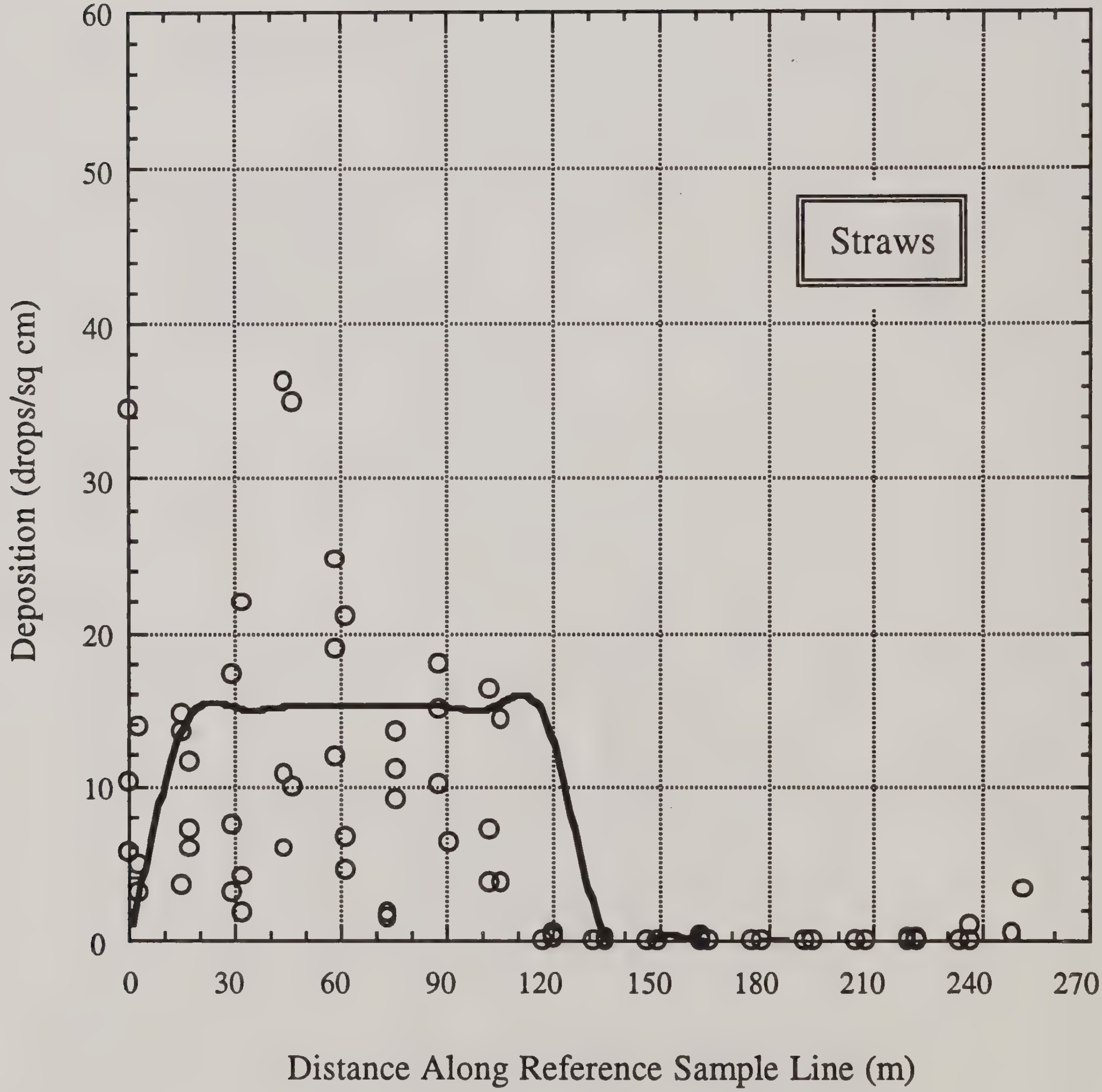


Figure 34: Trial 1: FSCBG predicted deposition over a reference sample line, straw samplers at **4.0-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

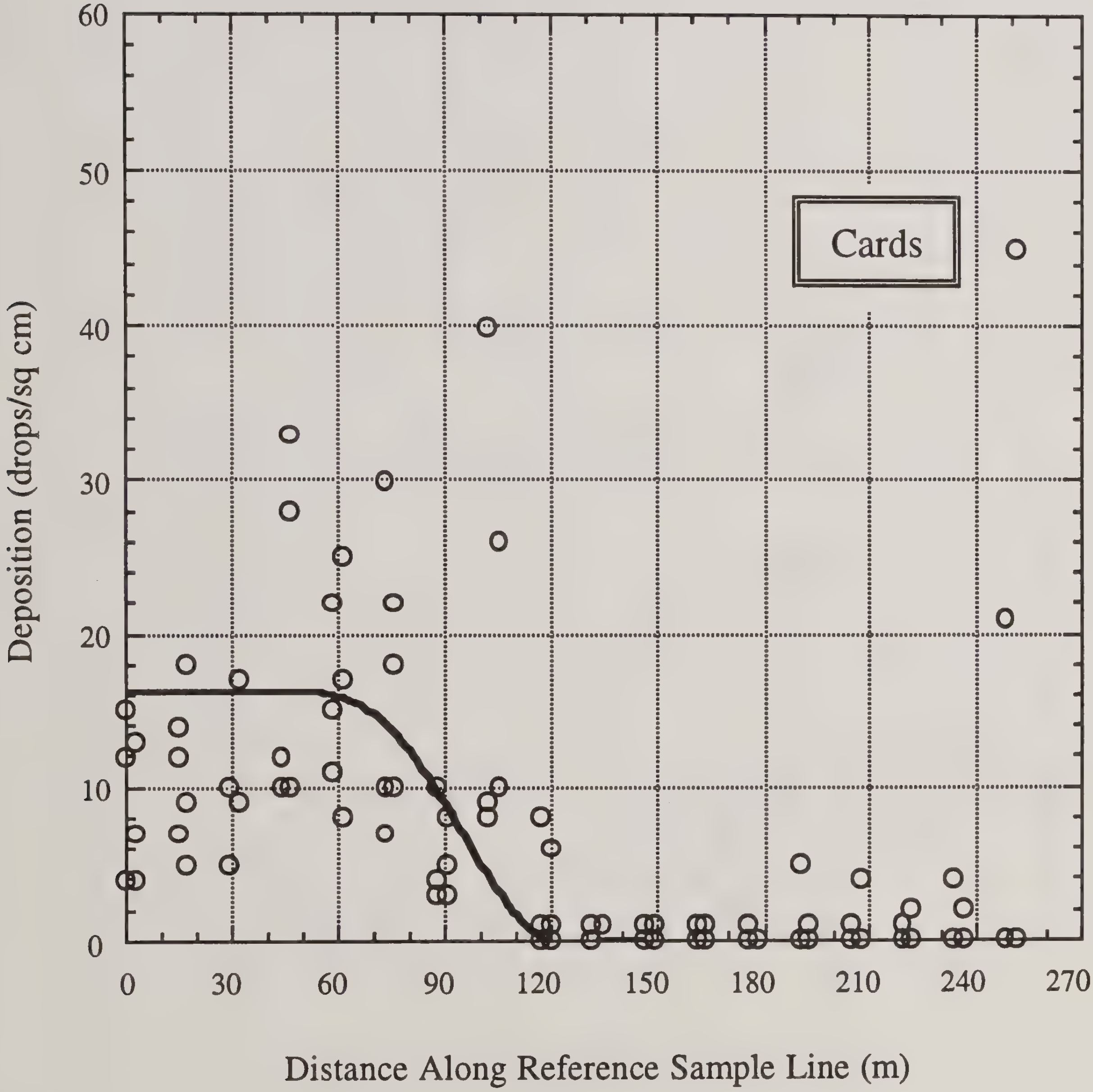


Figure 35: Trial 2: FSCBG predicted deposition over a reference sample line, card samplers at **4.0-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

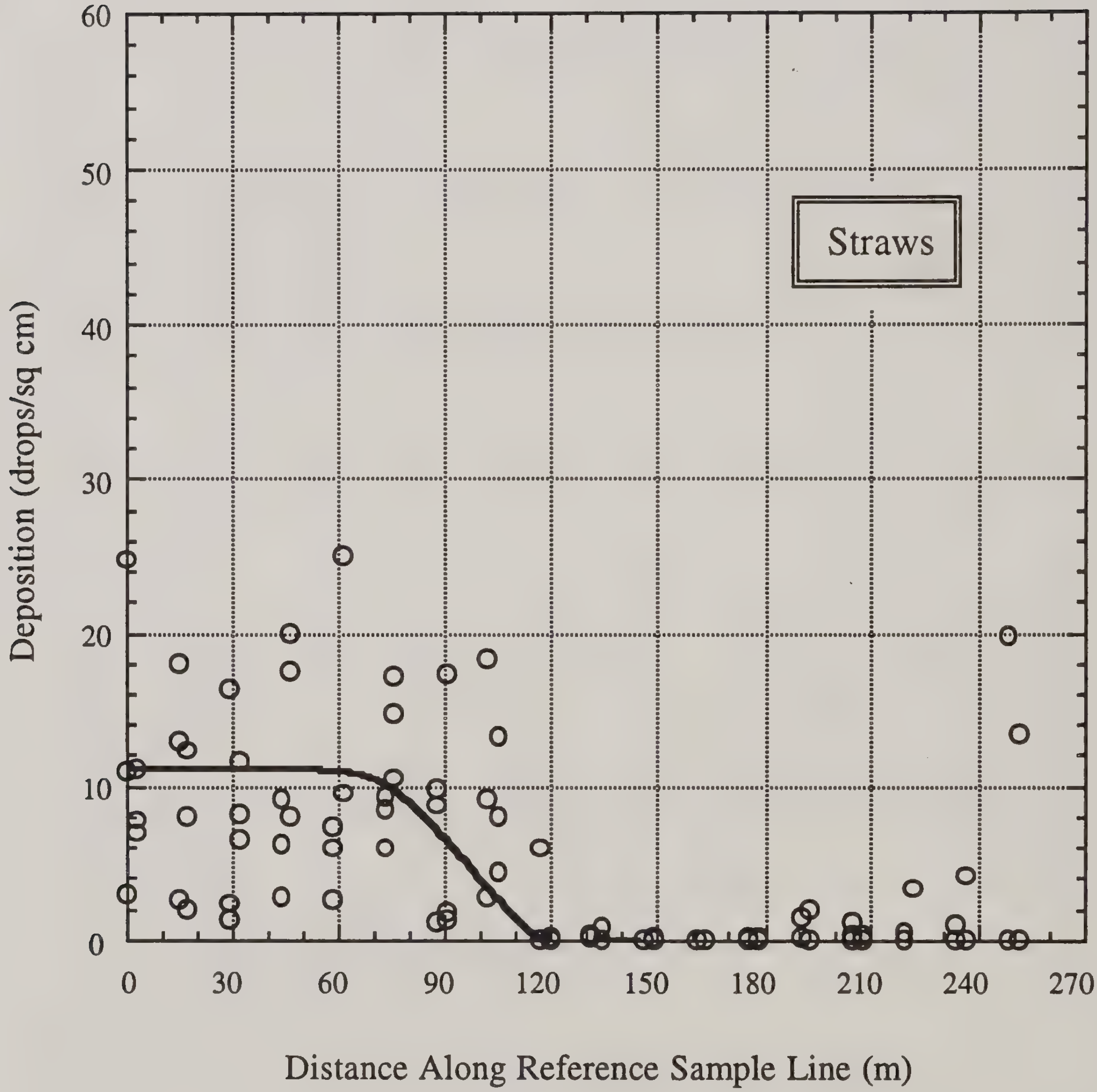


Figure 36: Trial 2: FSCBG predicted deposition over a reference sample line, straw samplers at **4.0-meter** elevation, compared to field test deposition. Deposition is shown in drops per square centimeter. FSCBG predictions are shown as a solid line, field test data are shown as open circles.

Table 8: Mean FSCBG Predicted Deposition and Mean Deposition Observed in the Canopy and on the Ground for Treated Trees

	TRIAL 1 (drops/sq cm)		TRIAL 2 (drops/sq cm)	
ELEVATION	FSCBG	Field Test	FSCBG	Field Test
Ground, cards	16	17	10	10
2.7 meters, cards	19	11	12	10
2.7 meters, straws	14	10	8	6
4.0 meters, cards	20	17	13	13
4.0 meters, straws	13	12	10	10

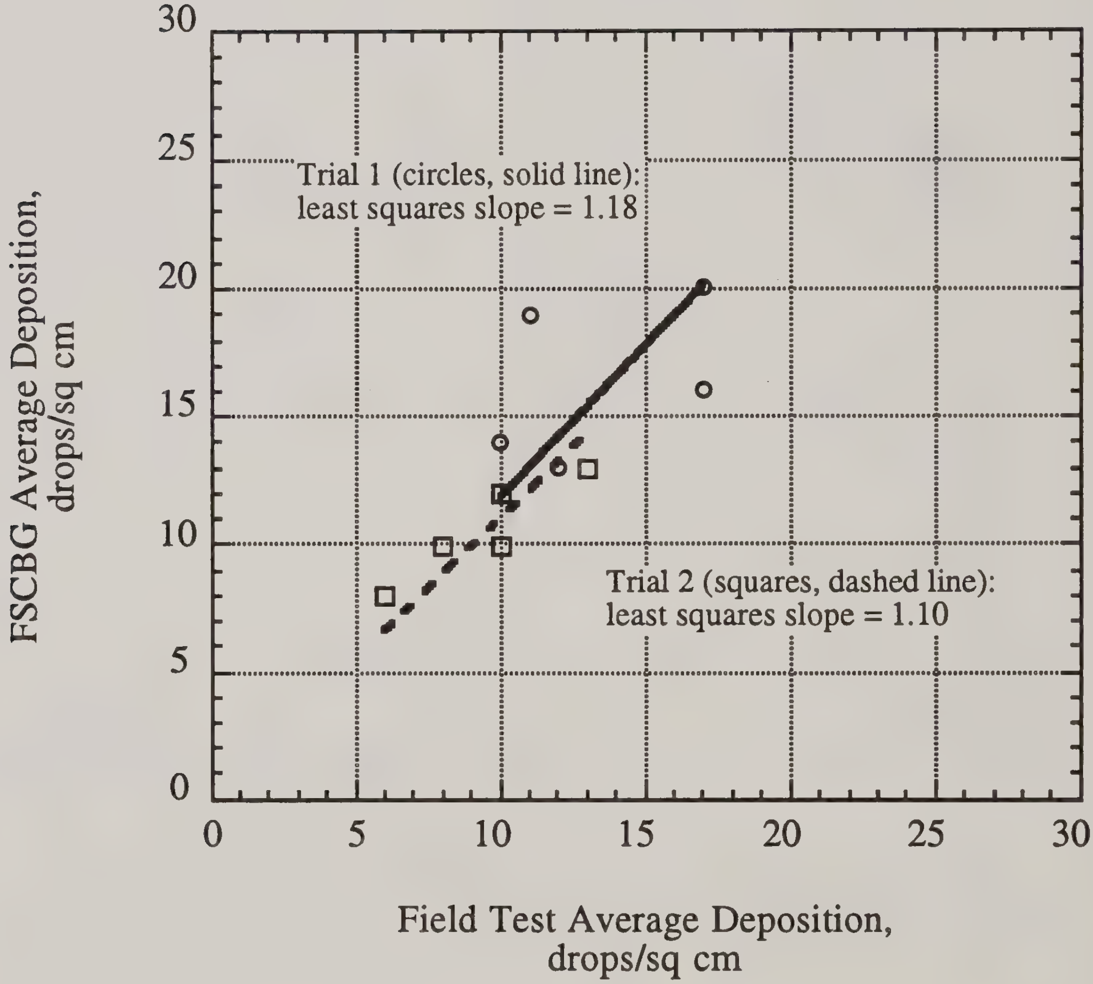


Figure 37: Predicted mean deposition, in drops per square centimeter, versus mean deposition observed, for both types of collectors and at all three elevations: data for trial 1 (February 25) are shown as open circles, and for trial 2 (March 3) as open squares. Correlation of mean predicted deposition to mean observed deposition: $R^2 = 0.44$ for trial 1, $R^2 = 0.90$ for trial 2.

5. Evaluation of Downwind Drift Data

The 1992 Charter almond orchard trials were designed to assess drift downwind of the treatment blocks. Lines of sample trees extended beyond the two treatment blocks into untreated control blocks (as shown in Figure 1 and discussed in section 2.2). The final ten sample trees on each line were in untreated areas; hence, deposition recorded on samplers around these trees can be used to assess drift.

Figures 10 through 19 clearly show that for both trials, deposition outside of the treatment block is minimal along the sample line (beyond 120 meters). Twig sample data for trial 1 (shown in Figure 21) also does not indicate significant drift along the sample line. Roltsch et al. (1995) note that off-target droplet densities decreased sharply despite the relatively high crosswind present in trial 2 (nearly 3 m/s from approximately 170 degrees). They go on to point out that for studies where insect migration is not of concern, plot size can be reduced by several rows if applications are made when wind speeds are less than those experienced in the Charter orchard trials. However, as mentioned in the previous two sections, although the level of deposition observed along the sample line falls off dramatically outside the treatment blocks for each trial, there is evidence of drift.

To further assess drift from the field deposition data, it is most instructive to view the deposition by sample line, as shown in Figures 3 through 8. In each of these figures, the bottom plot shows deposition across the entire width of the orchard test area, starting at the western edge of the first treatment block and ending at the eastern edge of the second untreated control block. Although the two sample lines shown in the bottom plot are separated by 73 meters in the north-south direction (see Figure 1), the orchard canopy is assumed to be similar throughout the test area, and deposition over these two lines can be regarded as a continuous profile from west to east across the orchard. Viewed in this way, there appears to be drift occurring to the west of the second line of samplers (approximately 190 to 250 meters east of the western edge of block 1). The wind direction in trial 2 was approximately 170 degrees; since the wind was coming from the south southeast some drift to the west of the sample lines could be expected. However, the wind in trial 1 was recorded as coming from 320 degrees, and is modeled in this report as nearly a headwind, yet there was a higher level of deposition observed to the west of sample line 2 than there was to the east of all three sample lines. Assuming that the pilot did turn off the spray at the edges of the treatment plots, there was measurable drift to the west of treatment block 2 during both trials. Since the sample lines in each block were not extended to the west of the block, spray drifting in that direction may not have been accounted for in the data collected.

In trial 1, drift was observed primarily on the ground samplers. In trial 2, during which there was a crosswind (between 2 and 4 m/s), the drift was more pronounced, was observed at each elevation in the canopy, and appears to have been mostly to the west of the edge of block 2, indicating that the downwind direction may actually have been from east to west. Figure 38 shows drop deposition data observed on ground cards along the end of sample line 1 and the beginning of sample line 2, for both trials (beginning 150 meters to the east of the western edge of treatment block 1, and ending 450 meters to the east of the western edge of treatment block 1). The edges of treatment bock 2 and the first and last swaths flown over the block are shown for reference. In trial 2 the beginning of the second sample line (i.e., the first sample tree position in treatment block 2) appears to have been

approximately 50 meters to the east of the edge of the deposition profile that was observed. Similar drift may have occurred to the west of sample lines 1 and 3.

As noted, the higher crosswind in trial 2 seems to have caused more drift at each elevation than the more quiescent meteorological conditions during trial 1. Ground deposition levels at the first tree position along the sample lines in trial 1 (on the western edges of the treatment blocks) are approximately 10 drops per square centimeter, or 60% of the mean level of ground deposition in the treatment block. In the canopy, deposition at the same place (the western edge of the treatment block) is half that level. Deposition levels on the ground and in the canopy have decreased to nearly zero approximately 25 meters to the west of the western edge of the treatment block 2. In trial 2, on the other hand, ground and canopy deposition levels at the western edge of treatment block 2 are at least as high as the mean levels of ground and canopy deposition in the block. As mentioned above, ground and canopy deposition observed in trial 2 does not decrease to nearly zero until approximately 50 meters to the west of the edge of treatment block 2.

In addition to the differences in meteorological conditions between the two Charter trials, the canopy was in different stages of flower and foliage during trial 1 (bloom expansion, in February) and trial 2 (petal fall, in March). Even in the more turbulent wind conditions during trial 2, the denser petal fall canopy would likely have captured more of the finely atomized spray from the Micronairs (as discussed in section 2.5) than the sparser popcorn (bloom expansion) canopy. The denser foliage might also continue to capture spray drifting outside the treatment area, in the untreated control blocks, to a greater extent than the popcorn foliage.

FSCBG predictions of deposition along a single sample line (shown in Figures 27 through 36) drop off at the eastern edge of the treatment plots just as the observed deposition drops off. Along a reference sample line as defined in the previous section, FSCBG predictions of deposition over the untreated control areas cannot duplicate the sudden increase in deposition observed at the western end of this line due to drift to the west of the treatment areas (discussed above). However, if the FSCBG simulations of trials 1 and 2 are redone with discrete samplers placed to the west of the first position shown in Figures 27 through 36, the resulting deposition profiles more closely match the profiles indicated by individual sample lines. Figure 38 shows the observed deposition for the last 60 meters of sample line 1 and the first 120 meters of sample line 2 (trees 15 through 26 in Figure 1), and the corresponding FSCBG predicted deposition for ground card samplers, trials 1 and 2. The general shape of the predicted deposition profile to the west of the treatment block as well as the level of deposition predicted agrees well with observed field data, particularly for trial 2. Similar agreement was found with field data from each elevation in the canopy.

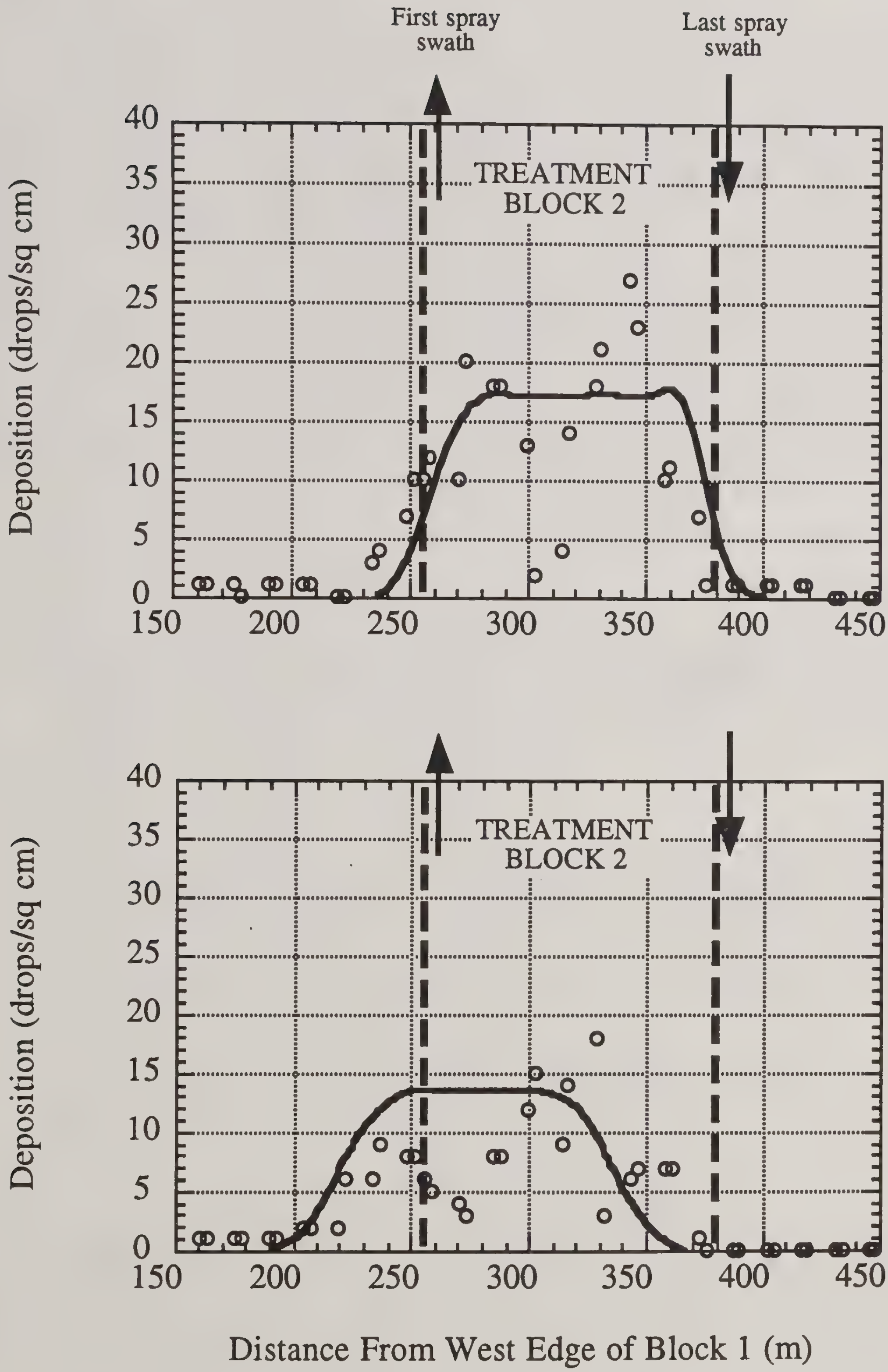


Figure 38: Drop deposition (in drops per square centimeter) on ground cards along the end of sample line 1 and the beginning of sample line 2, for trial 1 (top) and trial 2 (bottom): field data are shown as open circles, FSCBG predicted deposition is shown as a solid line.

6. Summary of Results

Data from the Charter almond orchard study presented in this report provide an opportunity to exercise FSCBG canopy modeling capabilities as well as FSCBG modeling capabilities for different types of discrete receptors. Canopy deposition at two elevations and ground deposition under the canopy were evaluated for two types of collectors: horizontally placed cards and horizontally placed straws. Field test deposition data, which show a large degree of scatter at sample positions along the line of sample trees, bracket the deposition predicted for both card and straw collectors, for all elevations and for both trials. Mean FSCBG predictions of drop deposition throughout the canopy and on the ground correlate well with mean observed deposition levels for cards and straws. Correlation of mean predicted and observed deposition shows least squares slopes of 1.18 and 1.10 for trials 1 and 2, respectively, and R^2= 0.44 for trial 1 and R^2= 0.90 for trial 2, well within acceptable levels of correlation for operational field trials.

The principal observations made in this report may be summarized as follows:

1. There is scatter in the drop deposition data collected in the canopy and on the ground, probably due to nonuniformity in canopy profile across the orchard or variation in release height or micrometeorology. The amount of scatter observed seems to be typical for this type of operational field test. Nevertheless, mean observed drop deposition for both trials is consistent with elevation in the canopy and position east and west of the sample tree centerline, confirming results developed previously by Roltsch et al. (1995).

2. The scatter in canopy deposition data is similar in magnitude for both card and straw collectors. This observation indicates that the scatter is due to nonuniformity of the canopy or variable test conditions (such as local release height and local wind conditions) rather than to differences inherent in the collectors themselves. For the same trial, mean deposition on straw samplers was lower than mean deposition on card samplers, at each elevation in the canopy; however, there is good correlation of card data to straw data throughout the canopy (Roltsch et al., 1995). Thus, both types of collectors would seem to be equally effective in describing the spray deposition pattern throughout the orchard, and the one that is easier to use would be the preferred one for future field studies.

3. Canopy deposition as measured by twig samples, cards and straws shows a similar pattern. Normalized twig sample data correlates well with normalized card and straw sampler data: $R^2 = 0.43$ for correlation of cards to twigs (least squares slope = 0.75) and $R^2 = 0.55$ for correlation of straws to twigs (least squares slope = 0.89). Considering the amount of scatter in the deposition data, which is typical for this type of operational field test, all three methods of sampling deposition in the canopy give consistent results. However, Roltsch et al. (1995) note that twig sampling is an expensive technique for use on a large scale, and therefore seems unfeasible for use in assessing routine application techniques.

4. Observed mean deposition levels at elevations of 4.0 meters and 2.7 meters were consistent with field data from other almond orchard trials (MacNichol, 1996b) for both canopy stages of flower and foliage. However, to fully account for deposition throughout the canopy, collectors should also be placed near the top of the canopy (approximately 6.0 meters in the case of the Charter orchard trees), since a significant portion of the spray is scavenged in the top of canopies.

5. Local meteorological data during the trials were recorded at a single location with hand-held instruments on-site and were not always consistent with the deposition profiles observed over sample lines. To achieve good correlation of drop deposition, the sensitivity of predicted deposition profiles to local wind conditions was evaluated, and local meteorology for both trials was adjusted accordingly. Despite good correlation of mean predicted and observed drop deposition, the canopy turbulence level at the time of each trial was only an estimate based on open terrain meteorology.

6. FSCBG predictions correlate well with the levels of deposition seen in the field trials, as well as with the deposition profiles over the lines of sample trees, despite possible variations in release height during the trials (and probable variations in micrometeorology). Mean values of predicted and observed deposition for the trials correlate well, least squares slopes of 1.18 for trial 1 and 1.10 for trial 2; $R^2 = 0.44$ for trial 1 and $R^2 = 0.90$ for trial 2.

7. A considerable amount of off-target drift was observed to the west of the sample lines laid in the orchard after trial 2, but most of the sample positions in untreated areas were placed to the east of the treatment blocks. Thus, off-target deposition was probably not completely accounted for by the placement of samplers. As stressed in Barry et al. (1993), samplers must be carefully placed to recover a representative and accurate mean deposition profile, particularly in cases with a canopy present (mostly because of wind direction shifts within the canopy).

8. FSCBG predictions of off-target drift were consistent with available field data.

One of the objectives of the Charter almond orchard study was to determine the biological effectiveness of each Bt application. However, Roltsch et al. (1995) estimated that less than 20% of shoot strikes were actually counted in the samples taken from the trees at the orchard, and therefore discounted the biological data gathered after the trials. Dose-response information on pests as well as sensitive species in off-target areas is essential to achieve biologically effective spray application while minimizing environmental insult to non-target areas. However, this type of information is difficult and costly to gather in the field.

Off-target pesticide drift is also of key importance to the efficacy of an aerial application, and to concerns over survival of non-target species. Even if drift outside the treatment blocks is minimal, if the target pest (or a non-target species) is highly sensitive to

Bt then slight drift could cause mortality in adjacent areas of the orchard. Accurate assessment of this aspect of the spray mission is an essential aspect of research studies on aerial spraying (it was another of the stated objectives of the Charter trials). It would appear, from the data examined here, that, with due consideration to project budget, sample lines should be extended to either side of a treatment area (not just in the direction assumed to be downwind). Despite careful test planning, the operational spray window opens for only a brief time, and meteorological conditions over the test site can be variable during that time.

Deposition beneath an aircraft can be concentrated, and off-target drift can therefore be reduced, by rigorous control (or awareness in the case of meteorological conditions) of those mission variables which have the greatest impact on spray deposition in the canopy and on the ground: release height, spraying speed, wind direction and wind speed. While the last two are somewhat unpredictable due to atmospheric turbulence, the first two can and should be maintained as closely as possible during the spray run.

As mentioned in the foreword, field tests such as the Charter orchard trials are subject to funding and manpower limitations as well as lack of or uncertain availability of aircraft and instrumentation. Nevertheless, the field data resulting from these trials are consistent for all types of sampling methods employed, and are consistent with other operational field trials in broadleaf orchards, and are an important element in understanding the economics and operational issues involved in ultra low volume applications of biopesticides.

7. Acknowledgments

The Charter orchard study described herein was made possible by the outstanding cooperation of Ray Charter, Frank Zalom, Gary Kirfman, Anita MacMullen, John Edstrom, Jim Cook. Pat Skyler was especially helpful in providing FSCBG model run files of the Charter orchard.

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9. Appendix

The Appendix contains field test drop deposition data from Charter orchard trials 1 and 2. For each trial, data from Kromekote card samplers are shown first, followed by data from soda straw samplers. Tree numbers are as indicated in Figure 1: trees 1 through 18 were along sample line 1; trees 19 through 36 were along sample line 2; and trees 37 through 54 were along sample line 3. "East" denotes samplers placed on the east side of the sample tree, and "west" denotes samplers placed on the west side of the tree. Dashes denote missing samplers (J.W. Barry, private communication, 1992).

Drop data from Kromekote cards are in drops per square centimeter, and drop data from soda straw samplers are in drops per 2 linear inches of straw. The soda straw data were converted to drops per square centimeter for comparison with card data and FSCBG simulations of the trials (J.W. Barry, private communication, 1992).

TRIAL 1, February 25, 1992: Kromekote Cards - Ground
(drops per square centimeter)

Tree Number	East	West	Tree Number	East	West
1	8	5	41	1	0
2	5	9	42	1	1
3	18	22	43	1	1
4	56	30	44	1	1
5	38	33	45	2	1
6	--	18	46	2	5
7	18	30	47	11	8
8	8	6	48	10	20
9	8	14	49	50	25
10	1	1	50	23	25
11	1	1	51	9	7
12	1	1	52	13	6
13	0	1	53	14	20
14	1	1	54	12	7
15	1	1			
16	0	0			
17	4	3			
18	10	7			
19	12	10			
20	20	10			
21	18	18			
22	2	13			
23	14	4			
24	21	18			
25	23	27			
26	11	10			
27	1	7			
28	1	1			
29	1	1			
30	1	1			
31	0	0			
32	0	0			
33	0	0			
34	1	0			
35	--	1			
36	--	--			
37	--	--			
38	1	1			
39	1	0			
40	1	0			

TRIAL 1, February 25, 1992: Kromekote Cards - Canopy, 2.7 meters
(drops per square centimeter)

Tree Number	East	West
1	4	5
2	5	8
3	8	9
4	26	5
5	16	--
6	12	18
7	--	13
8	18	13
9	5	6
10	1	2
11	1	1
12	1	9
13	--	1
14	1	2
15	1	1
16	1	0
17	1	1
18	4	--
19	4	14
20	5	10
21	8	25
22	--	8
23	5	3
24	6	15
25	4	11
26	13	8
27	1	1
28	0	0
29	1	0
30	1	0
31	--	1
32	0	--
33	--	0
34	--	0
35	--	--
36	--	--
37	--	--
38	1	0
39	--	0
40	0	1

Tree Number	East	West
41	1	1
42	1	1
43	2	1
44	1	1
45	1	2
46	--	2
47	--	7
48	--	7
49	15	16
50	2	25
51	8	4
52	20	5
53	12	--
54	26	13

TRIAL 1, February 25, 1992: Kromekote Cards - Canopy, 4.0 meters
(drops per square centimeter)

Tree Number	East	West
1	8	14
2	14	3
3	19	14
4	45	9
5	45	16
6	13	15
7	--	8
8	27	5
9	3	10
10	1	1
11	1	1
12	7	1
13	--	0
14	1	2
15	1	1
16	0	0
17	1	0
18	6	4
19	7	14
20	12	15
21	27	--
22	--	36
23	--	15
24	36	15
25	13	--
26	9	15
27	1	1
28	1	0
29	1	0
30	1	1
31	--	1
32	0	--
33	--	0
34	--	0
35	--	--
36	--	--
37	--	--
38	0	0
39	1	0
40	0	0

Tree Number	East	West
41	0	0
42	0	5
43	0	1
44	1	2
45	2	3
46	--	1
47	--	7
48	--	--
49	45	9
50	18	18
51	36	9
52	13	11
53	11	0
54	18	4

TRIAL 1, February 25, 1992: Soda Straws - Canopy, 2.7 meters
(drops per 2 linear inches)

Tree Number	East	West
1	16	75
2	19	16
3	--	51
4	162	34
5	60	37
6	--	45
7	--	91
8	96	3
9	4	7
10	0	0
11	0	1
12	1	0
13	--	0
14	0	0
15	0	0
16	0	0
17	1	0
18	5	11
19	0	19
20	16	55
21	63	26
22	--	22
23	30	15
24	24	4
25	25	26
26	52	26
27	0	0
28	0	--
29	--	0
30	0	1
31	0	--
32	0	--
33	--	0
34	--	0
35	--	--
36	--	--
37	--	--
38	0	--
39	0	0
40	0	0

Tree Number	East	West
41	0	0
42	0	0
43	0	0
44	0	--
45	9	1
46	--	8
47	1	18
48	--	58
49	17	111
50	106	90
51	66	7
52	40	40
53	66	--
54	70	120

TRIAL 1, February 25, 1992: Soda Straws - Canopy, 4.0 meters
(drops per 2 linear inches)

Tree Number	East	West
1	25	52
2	36	18
3	110	87
4	175	54
5	106	124
6	46	8
7	--	90
8	72	19
9	3	--
10	0	0
11	0	0
12	0	1
13	--	0
14	0	0
15	0	0
16	0	1
17	5	0
18	17	3
19	16	173
20	30	74
21	9	38
22	--	182
23	23	95
24	56	--
25	32	75
26	19	82
27	1	0
28	0	--
29	0	0
30	--	2
31	--	0
32	0	--
33	0	0
34	--	0
35	--	--
36	--	--
37	--	--
38	0	0
39	1	0
40	0	0

Tree Number	East	West
41	0	0
42	0	0
43	0	0
44	0	0
45	1	--
46	--	0
47	--	36
48	--	51
49	68	9
50	34	60
51	50	30
52	21	16
53	58	68
54	70	29

TRIAL 2, March 3, 1992: Kromekote Cards - Ground
(drops per square centimeter)

Tree Number	East	West
1	15	16
2	13	13
3	8	9
4	29	9
5	16	19
6	4	5
7	4	2
8	4	5
9	1	1
10	1	1
11	1	0
12	1	1
13	1	1
14	1	1
15	2	2
16	6	2
17	9	6
18	8	8
19	5	6
20	3	4
21	8	8
22	15	12
23	14	9
24	3	18
25	7	6
26	7	7
27	0	1
28	0	0
29	0	0
30	0	0
31	0	0
32	0	0
33	0	0
34	0	0
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0

Tree Number	East	West
41	0	0
42	0	0
43	1	0
44	0	0
45	0	0
46	0	4
47	9	16
48	6	9
49	10	3
50	7	11
51	7	13
52	14	14
53	6	8
54	4	5

TRIAL 2, March 3, 1992: Kromekote Cards - Canopy, 2.7 meters
(drops per square centimeter)

Tree Number	East	West
1	13	12
2	11	9
3	3	6
4	25	12
5	34	17
6	12	5
7	3	1
8	4	12
9	1	1
10	0	0
11	0	1
12	1	1
13	1	0
14	1	1
15	2	1
16	--	2
17	12	2
18	23	10
19	4	5
20	7	7
21	9	4
22	10	10
23	8	3
24	5	10
25	6	3
26	6	7
27	0	0
28	--	--
29	0	0
30	0	0
31	0	0
32	--	--
33	0	0
34	--	--
35	0	0
36	0	0
37	0	0
38	0	0
39	0	1
40	0	0

Tree Number	East	West
41	0	0
42	0	0
43	--	0
44	--	0
45	--	0
46	--	4
47	11	--
48	4	11
49	10	4
50	15	16
51	15	19
52	13	10
53	7	7
54	12	10

TRIAL 2, March 3, 1992: Kromekote Cards - Canopy, 4.0 meters
(drops per square centimeter)

Tree Number	East	West
1	7	12
2	18	12
3	17	10
4	28	12
5	25	22
6	18	7
7	3	3
8	10	9
9	1	1
10	1	1
11	1	1
12	1	1
13	0	1
14	1	5
15	4	1
16	2	1
17	2	4
18	45	21
19	4	4
20	5	14
21	9	5
22	10	10
23	8	15
24	22	30
25	8	4
26	26	8
27	0	0
28	--	--
29	0	0
30	0	0
31	0	0
32	--	--
33	0	0
34	--	--
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0
41	0	0
42	0	0
43	--	0
44	--	1
45	--	0
46	6	8
47	--	40
48	5	10
49	10	10
50	17	11
51	33	--
52	17	--
53	9	7
54	13	15

TRIAL 2, March 3, 1992: Soda Straws - Canopy, 2.7 meters
(drops per 2 linear inches)

Tree Number	East	West
1	6	40
2	42	17
3	10	23
4	--	75
5	71	38
6	39	12
7	5	5
8	17	22
9	0	1
10	0	0
11	0	2
12	1	1
13	5	1
14	--	4
15	3	1
16	6	1
17	27	1
18	121	41
19	13	20
20	20	16
21	40	10
22	74	16
23	24	--
24	50	19
25	4	18
26	26	30
27	0	0
28	--	--
29	0	0
30	--	0
31	0	0
32	--	--
33	0	0
34	--	--
35	--	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0

Tree Number	East	West
41	0	0
42	0	0
43	--	0
44	0	--
45	0	0
46	0	0
47	7	33
48	38	46
49	40	3
50	35	36
51	50	46
52	16	13
53	20	12
54	29	8

TRIAL 2, March 3, 1992: Soda Straws - Canopy, 4.0 meters
(drops per 2 linear inches)

Tree Number	East	West
1	35	124
2	62	65
3	58	82
4	100	14
5	125	37
6	74	43
7	9	6
8	40	46
9	0	0
10	4	2
11	1	0
12	0	0
13	1	0
14	10	8
15	2	6
16	17	3
17	21	5
18	67	99
19	39	15
20	10	90
21	33	7
22	40	31
23	48	13
24	53	47
25	87	49
26	66	14
27	0	0
28	--	--
29	--	--
30	0	0
31	--	1
32	--	--
33	--	0
34	--	--
35	0	--
36	0	0
37	0	0
38	0	0
39	--	0
40	0	2

Tree Number	East	West
41	0	1
42	0	0
43	--	0
44	0	0
45	0	1
46	1	30
47	22	92
48	7	44
49	86	30
50	48	30
51	88	46
52	41	12
53	40	13
54	56	55